A METHOD OF PREDICTING STATICAL STABILITY FROM HULL COEFFICIENTS

EDWARD A. TAYLOR
ROBERT D. BALLANTYNE
SPENCER REITZ

Library
U. S. Naval Postgraduate School
Monterey, California

Mark 137

Cambridge, Massachusetts,
May 20, 1948.

Professor J. S. Newell,
Secretary of the Faculty,
Massachusetts Institute of Technology
Cambridge, Massachusetts.

Dear Sir:

In accordance with the requirements for the Degree of Master of Science in Naval Construction and Engineering, we submit herewith a thesis entitled, "A Method of Predicting Statical Stability from Hull Coefficients."

A METHOD OF PREDICTING STATICAL STABILITY FROM HULL COEFFICIENTS.

by

Edward A. Taylor
Lieutenant Commander, U. S. Navy.
B.S., University of Washington, 1935

Robert D. Ballantyne
Lieutenant Commander, U. S. Navy.
B.S., Georgia School of Technology, 1938

Spencer Reitz
Lieutenant Commander, U. S. Navy.
B.S., University of Michigan, 1941

Submitted in Partial Fulfillment

of the Requirements for the Degree of

Master of Science in Naval Construction and Engineering

from the

Massachusetts Institute of Technology

1948

Thesis
T2

ACKNOWLEDGMENT

The authors wish to express their appreciation to Professors G. C. Manning and W. W. Robertson for their advice and assistance in conducting this investigation.

6930

TABLE OF CONTENTS

		PAGE
	Symbols	1
I.	Summary	3
II.	Introduction	7
III.	Procedure	9
IV.	Results	11
V.	Discussion of Results, Recommendations and Conclusion	54
VI.	Appendix	59
	A. Mathematical Analysis of GZ/B.	60
	B. Specific Application of Taylor's Mathematical Lines.	66
	C. References.	77

6330

SYMBOLS

B - 1. beam; 2. center of buoyancy.

b - block coefficient.

BM - transverse metacentric radius.

D - depth of section.

G - center of gravity.

GM - transverse metacentric height.

GZ - righting arm.

H - Draft.

I - transverse moment of inertia of waterplane.

K - keel point.

KB - vertical distance from keel to center of buoyancy.

KG - vertical distance from keel to center of gravity.

L - 1. length of ship; 2. a parameter used in Taylor's Mathematical Lines.

l - longitudinal coefficient.

m - midship section coefficient.

p - waterline coefficient.

θ - angle of inclination.

SYMBOLS (cont.)

Additional symbols appearing only in Appendix B are:

a_0 - acceleration of the curve at the bow or stern.

a_1 - acceleration of the curve at the midship section.

f - flare of the unit ship.

F - flare of the actual ship.

m_0 - section coefficient for zero flare.

m_s - section coefficient.

R - deadrise coefficient.

S - slope of the acceleration curve.

t - bow or stern tangent.

y_b - fraction of the midship beam.

I. SUMMARY

A. Object:

The object of this investigation was to develop a more accurate and convenient method than is currently available for predicting the Curve of Statical Stability from preliminary design information.

B. Method:

The original objective of this investigation was to continue the study made by Kelley, et al. (Ref. 3.) and Randall, et al. (Ref. 4.). A series of eight (8) hulls (Hulls A to H, incl.) had been developed and integration for values of GZ/B had been performed for Hulls A to F inclusive. Integration of hulls G and H was completed by the authors.

After compilation of integration data for the eight hulls was completed, a study of the parameters effecting statical stability was made. Mathematical analysis indicated $\left(\frac{\Delta}{b^3}\right)$, $\left(\frac{B}{H}\right)$ AND θ as the major variables. It was also recognized that $\left(\frac{D}{H}\right)$ and the form of the above-water body has a considerable effect.

Attempts to plot the integrated results of Hulls A to H in form of contours of GZ/B against the selected variables revealed the fact that the eight hulls were not geometrically ~~similar~~ related. It was concluded that a truly geometrically ~~similar~~ having a consistant geometrical relation series must be developed in order to provide accurate contours.

With recognition of the need for a related family, the authors made studies which would allow the most logical selection of the parent and which would provide knowledge of the proper method for the expansion of that parent into a family of hulls. The coefficients of the parent are such that they represent the mean of those used in normal merchant and Naval hulls. Transformation of the parent was made by giving equal numerical change in the block and waterplane coefficients while holding the midship coefficient constant. This allowed development of a six (6) hull family whose values of $\left(\frac{\nabla}{L}\right)^3$ would cover the range of normal hulls. The sectional area and waterplane curves, and the actual sections, of the hulls were developed through use of Taylor's Mathematical Lines (Ref. 6.).

A study of the effects of variation of B/H on statical stability was also performed. This indicated that the hulls should be integrated for B/H values of 2.25 to 3.75. It was also concluded that inclinations of 0, 15, 30, 40, 50, 60, 70, and 80 degrees should be used to provide accurate Statical Stability curves and to cover the normal range in which the designer is interested.

Since this thesis is only a phase of a long-range project, it is considered imperative that a rigid outline be given for the use of those who may choose to continue the investigation. The following recommendations are made:

a. Integration of Hulls 20 to 70 inclusive is to be performed with the following variation of the parameters:

B/H - 2.25, 2.50, 2.75, 3.00, 3.25, 3.50, 3.75

D/H - 1.40, 1.60, 1.80, 2.00

θ - 0, 15, 30, 40, 50, 60, 70 DEGREES.

This will provide values of GZ/B.

b. After compilation, the values of GZ/B are to be plotted as contours using $\left(\frac{\Delta}{b^3}\right)$ as the abscissae and θ as the ordinate. Contour sheets will be drawn for constant values of B/H and D/H. Thus twenty-four for each B/H value eight sheets of contours will be prepared.

c. Plotting of the contours will indicate whether the six hulls already developed will provide accurate contours. It may be necessary to develop additional hulls to introduce additional points.

d. With completion of the contour sheets, statical stability curves should be developed for a number of vessels of various types. This will allow comparison with the actual statical stability curves of the vessels and will provide indication as to the accuracy of the contours.

e. Finally, a study should be performed of the effects of variation of the above water body. This may allow correction for varying flare and shear to be introduced.

It is firmly believed that the contours developed in this manner will provide the designer with a means of quantitative analysis of the statical stability of a ship while in the preliminary design stage and will also provide a visual means for qualitative study of the subject.

II. INTRODUCTION.

In the preliminary design of a vessel it is desirable to determine the characteristics of the Statical Stability Curve. At the present time this is possible only after delineating the lines of the vessel. Normally the righting arms are determined from integration of the body plan for various angles of inclination.

A method leading to the selection of hull coefficients giving desirable stability characteristics, along with Taylor's method (Ref. 1.) of predicting hull resistance, would materially aid the designer. Selection on this basis would yield coefficients representing the most desirable balance between resistance and stability.

The problem of prediction of statical stability has been under constant investigation. The results obtained do not consistently predict the statical stability with sufficient accuracy for use. Some methods have been developed giving fair results for a particular type of vessel alone, but cannot be utilized for hulls which depart radically from this type.

Le Parmentier (Ref. 2.) developed a method in which righting arms are determined from tables. However, this method also requires the delineation of lines of the vessel.

This investigation, in the early stage, followed the line of thought established by Kelley, et. al. (Ref. 3.) and Randall, et al. (Ref. 4.) Analysis of the data obtained revealed an inconsistency in the variation of the coefficients of the hulls previously developed. The coefficients selected

by the previous investigators were found to have produced unrelated hull forms. For this reason the data could not be correlated.

The authors concluded that hull forms must of necessity be truly related in order that the data obtained might be correlated and plotted in useful form. This led to a study of the inter-relation of hull coefficients, and the method of variation of the coefficients to provide a suitable family of hulls.

III. PROCEDURE.

Curves of Statical Stability were determined for Hulls G and H, the offsets of which were set forth in Reference 4. The method used for the integration was as outlined in that reference.

In order to plot the data in useful form it was necessary to determine the basic parameters. From a mathematical analysis, (Appendix A.) utilizing Atwood's equation for righting arm (Ref. 5.) the basic parameters were found to be $\left(\frac{p^3}{b}\right)$, $\left(\frac{B}{H}\right)$ AND θ. In addition, it was obvious that $\left(\frac{D}{H}\right)$ and the form of the above-water body had a considerable effect.

Using the data from Hulls A to H inclusive, contours of constant GZ/B were plotted against $\left(\frac{p^3}{b}\right)$ and θ for constant values of $\left(\frac{B}{H}\right)$ and a given value of $\left(\frac{D}{H}\right)$. The results obtained, Figure VII, substantiated the selection of the parameters. However, these contours demonstrated the need for a related family of hulls in order to obtain fair and consistent contours.

The first step in the development of the family of related hulls was an analysis of the coefficients of form actually used in normal ships to determine the range of each and the inter-relation of the various coefficients. This was achieved by plotting values of (b) vs. (p) for actual vessels to establish the field applicable. (Figures VIII and IX.) Curves of constant $\left(\frac{p^3}{b}\right)$ were superimposed for the purpose of determining the required range of this parameter.

The variation of (b) with change in (p) was determined for Merchant and Naval vessels. Also the variation of (b) with change in (p) was determined for a geometrically developed series.

A parent hull was selected with due consideration for the proper range of the coefficients. Taylor's Mathematical Lines (Ref. 6.) were used in the development of the body plans. This method was selected in that reasonable hull forms, bearing a definite family relationship, could be developed without having to fair a complete set of lines.

Six (6) hulls were developed within the selected range of coefficients. The variation of the coefficients was controlled to yield equal increments of $\left(\frac{\nabla}{b^3}\right)$ so that the contours could be most conveniently plotted.

IV. RESULTS

TABLES OF GZ/B FOR HULLS (G) AND (H).

TABLE I.

RIGHTING ARMS, $\left(\frac{GZ}{B}\right)$ FOR HULL G.

Hull Coefficients

l	0.620
b	0.469
p	0.720
m	0.756

B/H 2.50

D/H	2.0	1.8	1.6	1.4
15°	.0206	.0206	.0206	.0206
30°	.0434	.0434	.0432	.0316
45°	.0731	.0650	.0450	.0146
60°	.0910	.0630	.0285	-.0128

B/H 3.00

D/H	2.0	1.8	1.6	1.4
15°	.0284	.0284	.0284	.0284
30°	.0760	.0760	.0712	.0520
45°	.1052	.0913	.0636	.0338
60°	.1091	.0794	.0449	.0062

B/H 3.50

D/H	2.0	1.8	1.6	1.4
15°	.0509	.0509	.0509	.0507
30°	.1024	.0999	.0901	.0634
45°	.1248	.1050	.0750	.0379
60°	.0974	.0674	.0519	.0121

TABLE II.

RIGHTING ARMS, $\left(\frac{GZ}{B}\right)$ FOR HULL H.

Hull Coefficients

l	0.620
b	0.469
p	0.670
m	0.756

B/H 2.50

D/H	2.0	1.8	1.6	1.4
15°	.0133	.0133	.0133	.0133
30°	.0362	.0362	.0315	.0185
45°	.0581	.0489	.0312	.0074
60°	.0736	.0488	.0153	-.0242

B/H 3.00

D/H	2.0	1.8	1.6	1.4
15°	.0323	.0323	.0323	.0323
30°	.0648	.0648	.0577	.0412
45°	.0920	.0755	.0555	.0233
60°	.0910	.0631	.0332	.0074

B/H 3.50

D/H	2.0	1.8	1.6	1.4
15°	.0427	.0427	.0427	.0426
30°	.0791	.0802	.0692	.0507
45°	.1068	.0896	.0673	.0364
60°	.0997	.0738	.0414	.0018

STATICAL STABILITY CURVES

HULLS G AND H.

FIGURE I.

HULL SERIES G

$B/H = 2.5$

R.O.H.
E.a.J.
J.R.

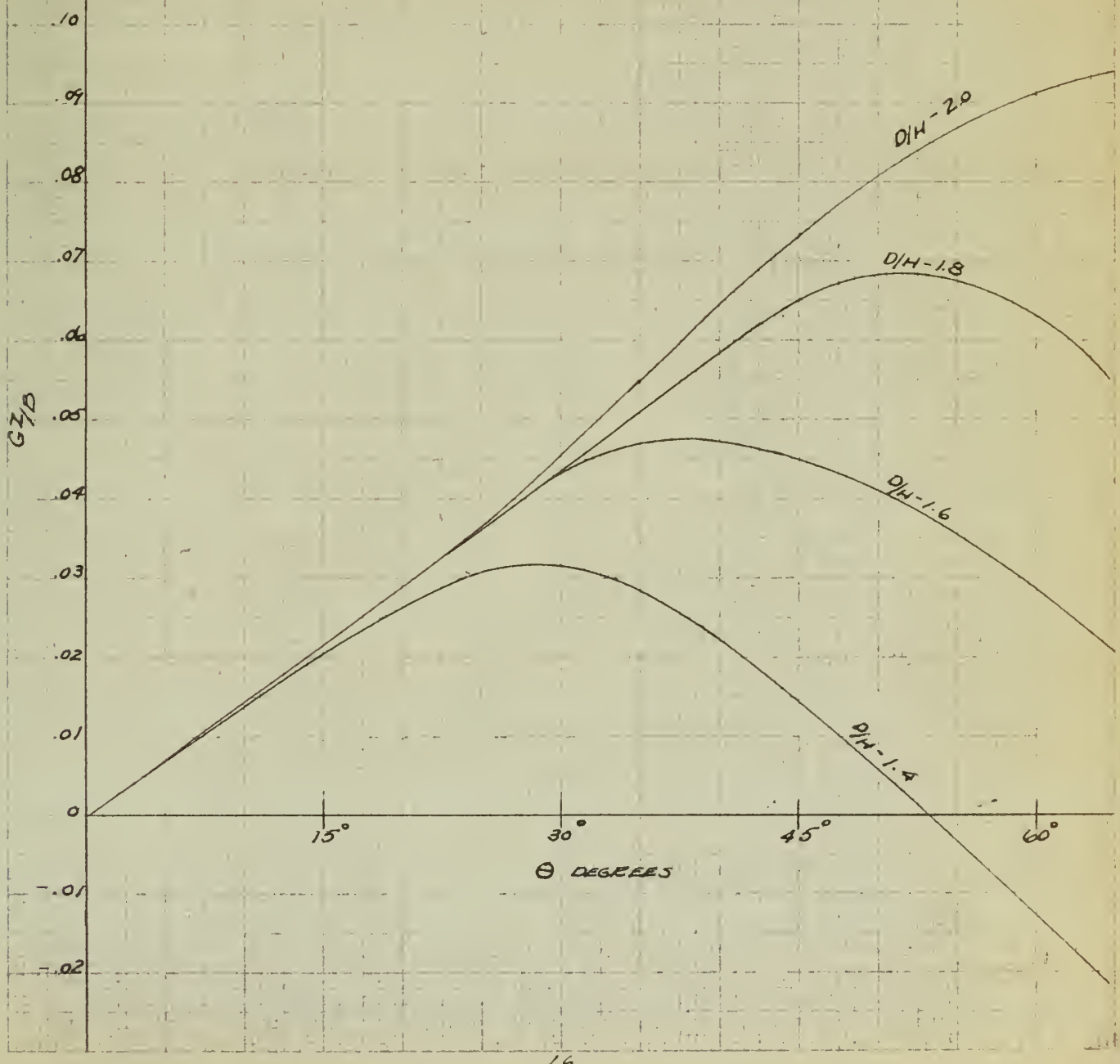


FIGURE II.

HULL SERIES G
B/H - 3.0

R.D.B.
E.A.D.
J.R.

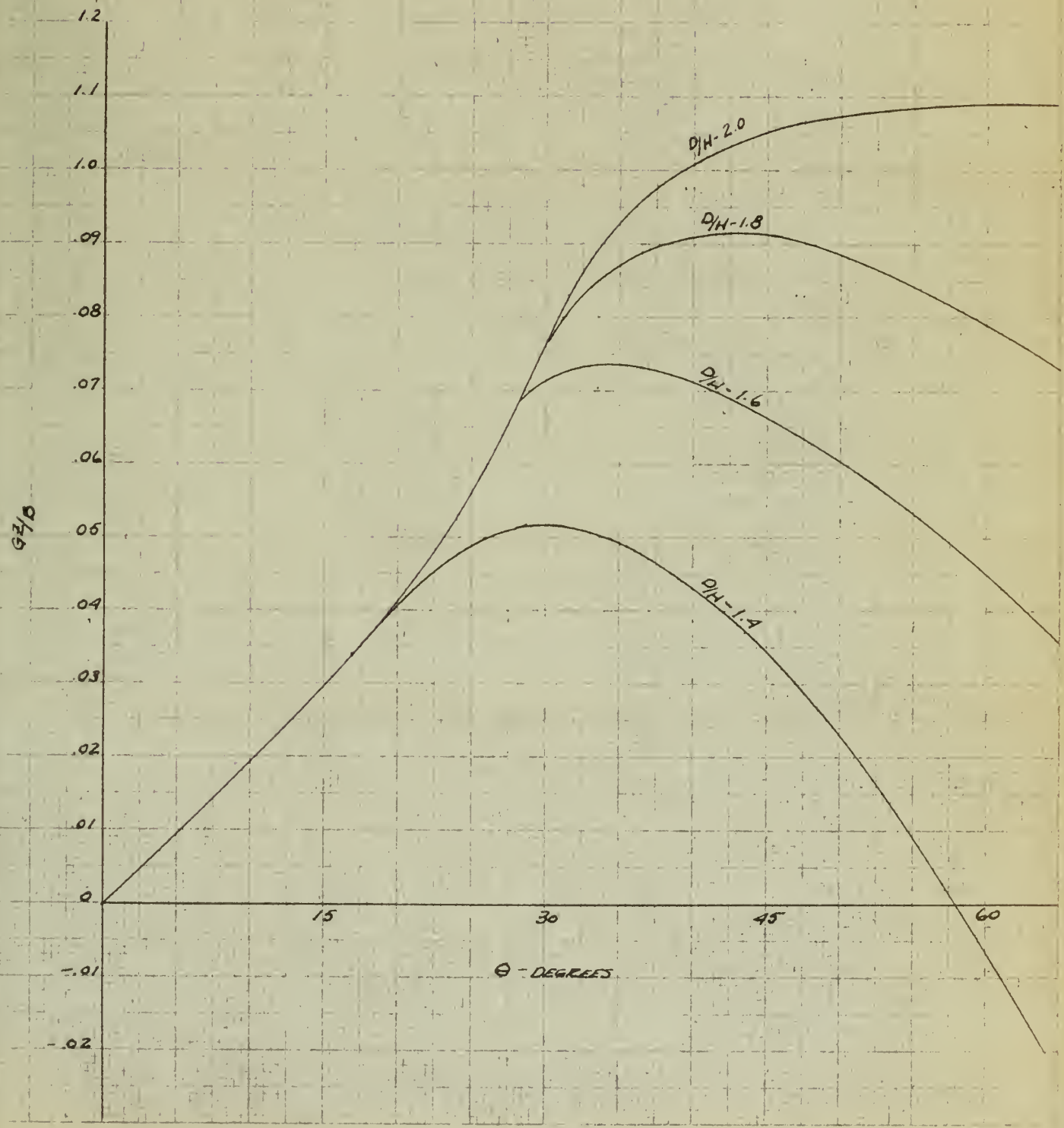


FIGURE III.

HULL SERIES G
B/H - 3.5

R.D.R.
E.A.S.
J.R.

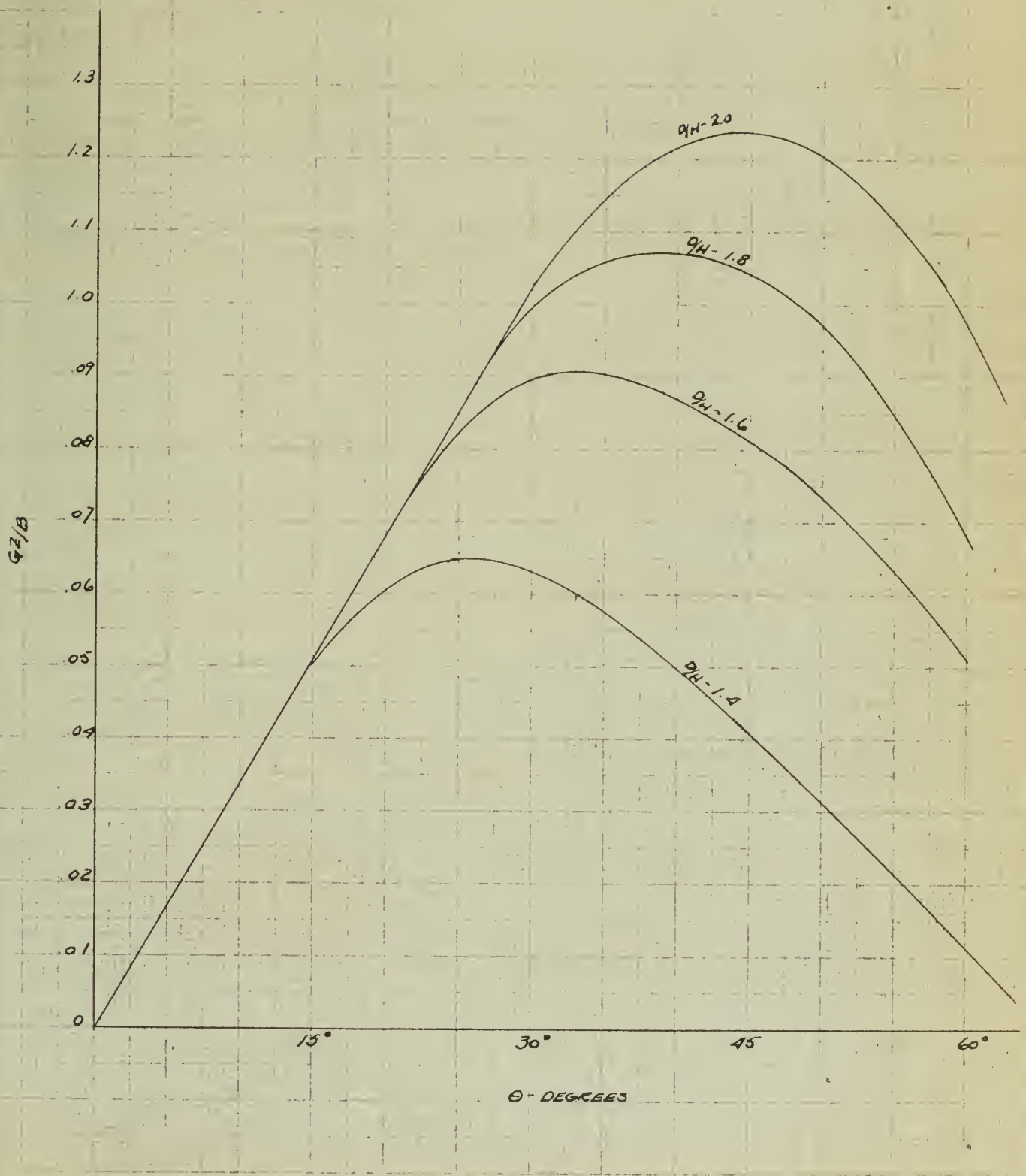


FIGURE IV.

HULL SERIES H
B/H - 2.5

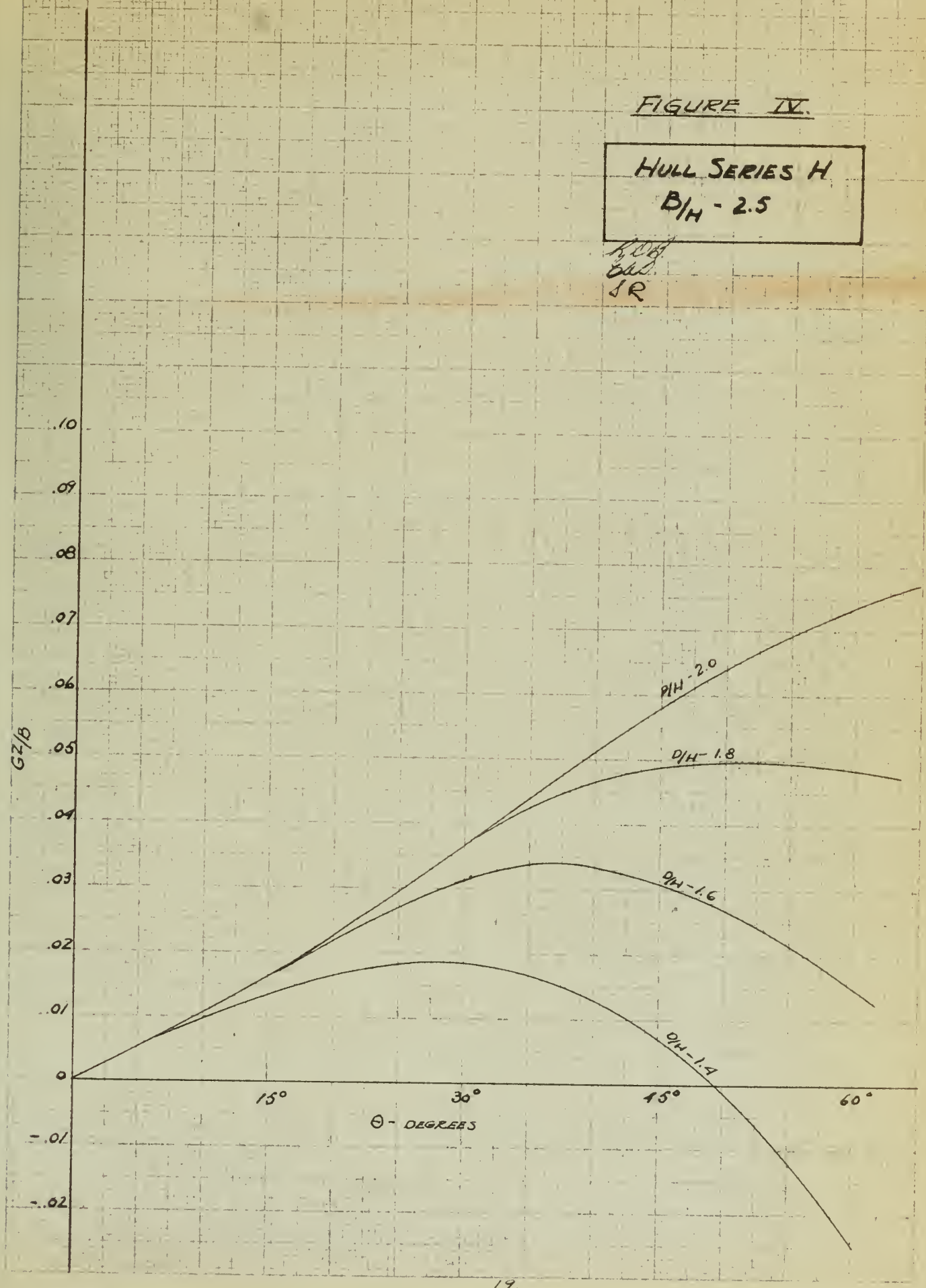


FIGURE V.

HULL SERIES H
B/H - 3.0

RDB
EAD
J.R

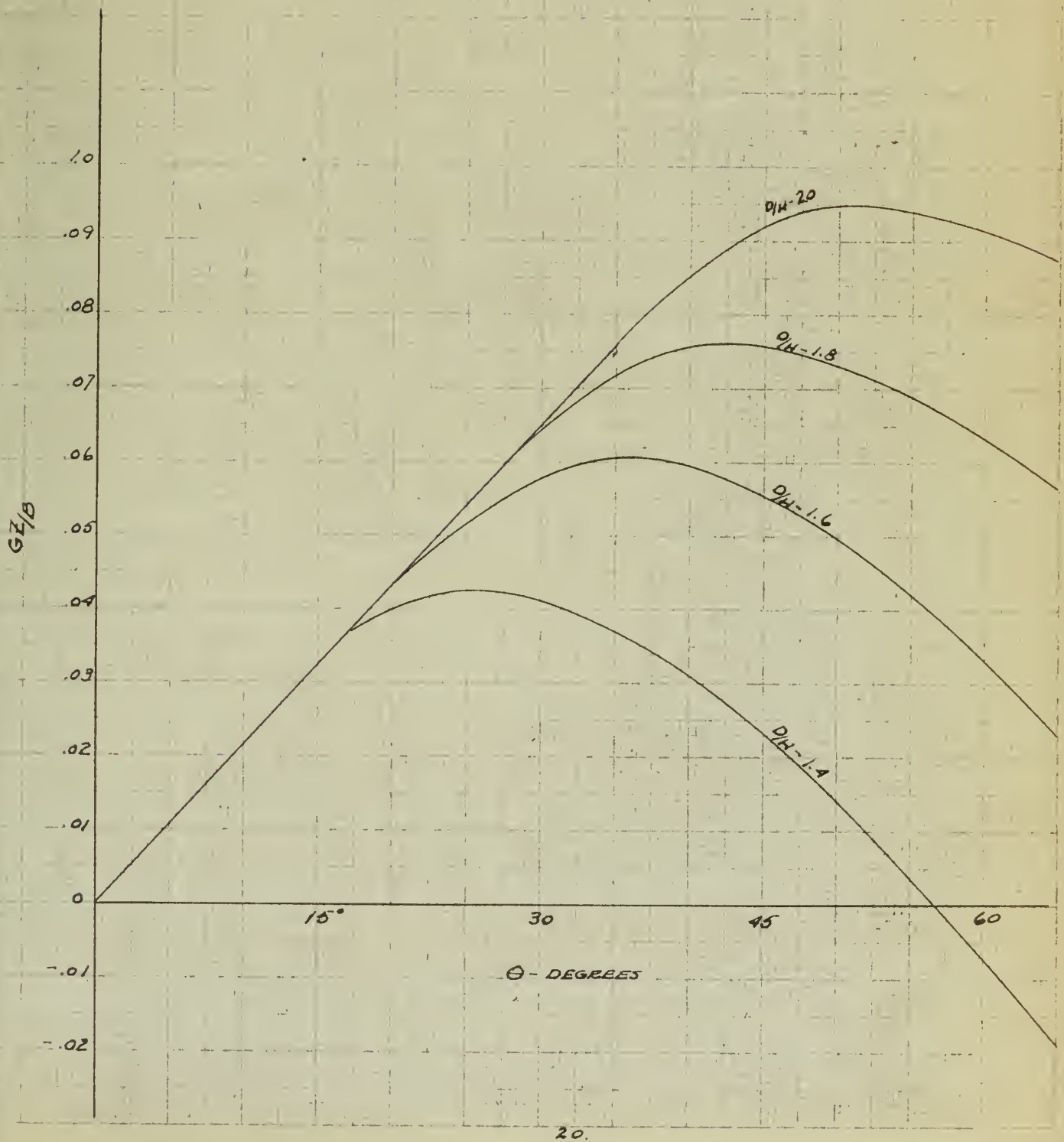
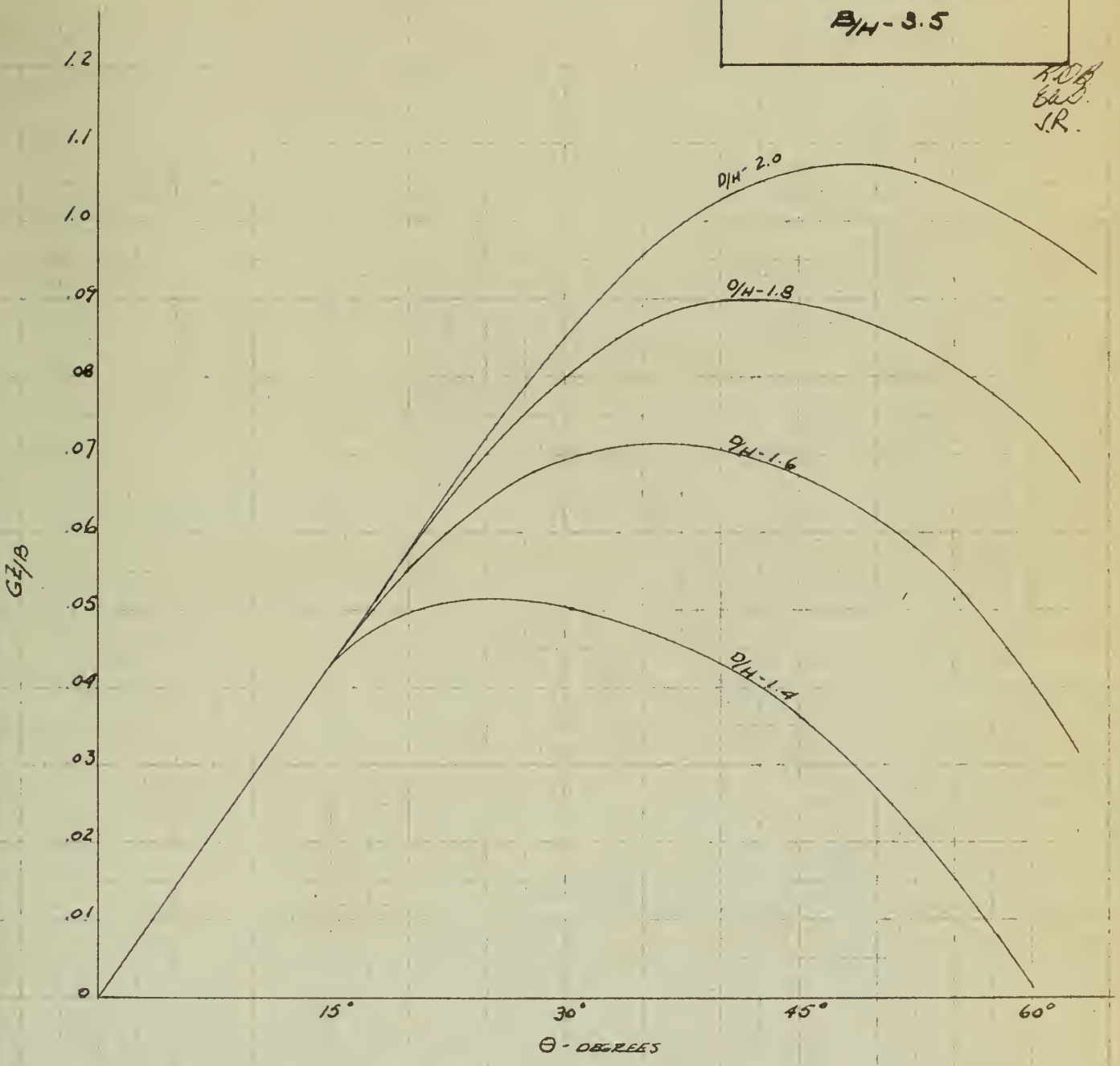


FIGURE VI.


HULL SERIES H
B/H - 3.5
KDB
EAC
J.R.
D/H - 2.0
D/H - 1.8
D/H - 1.6
D/H - 1.4
GZ/B
1.2
1.1
1.0
.09
.08
.07
.06
.05
.04
.03
.02
.01
0
15°
30°
45°
60°
Θ - DEGREES

CONTOURS OF GZ/B.

FOR HULLS (A) TO (H) INCLUSIVE.

B/H = 2.50

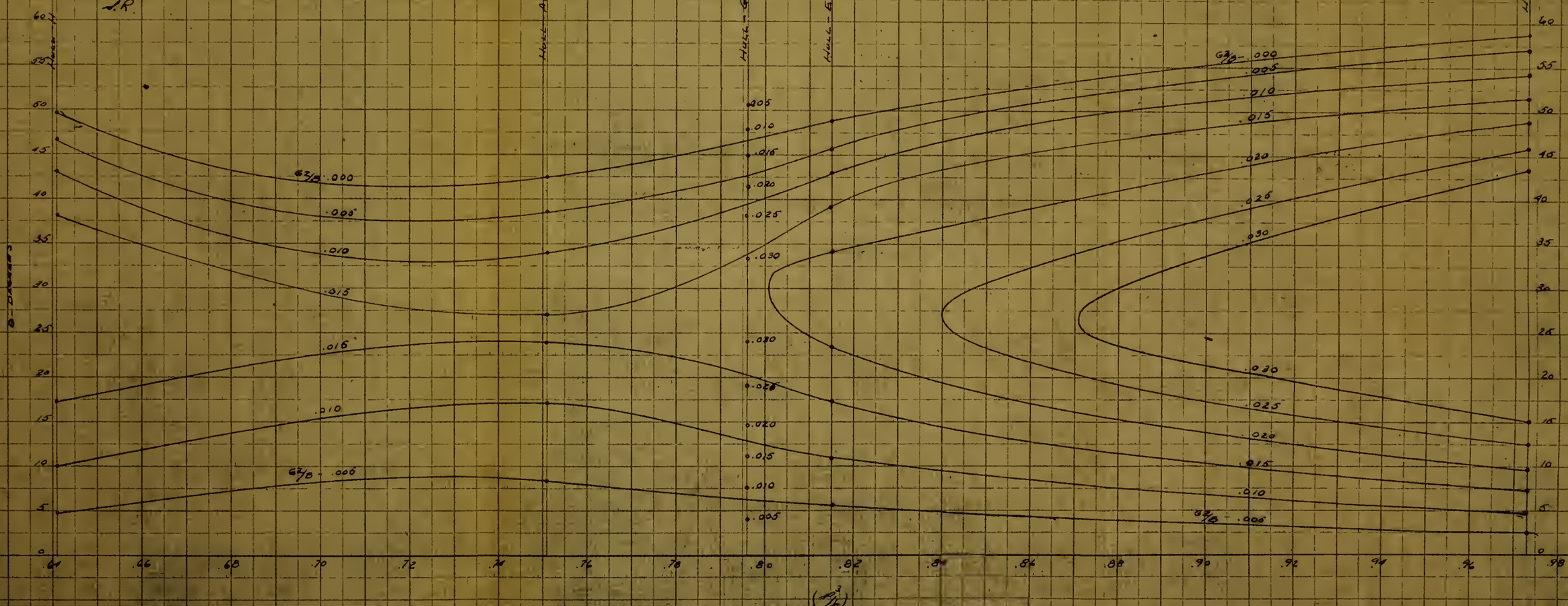
D/H = 1.40

FIG. VII

CONTOURS OF G_Z/D

$\Theta_H = 2.5$ $\Theta_H = 1.4$

APPD
BWJ
J.R.



CURVES OF VARIATION OF (b) AND (p).

FIGURE VIII.

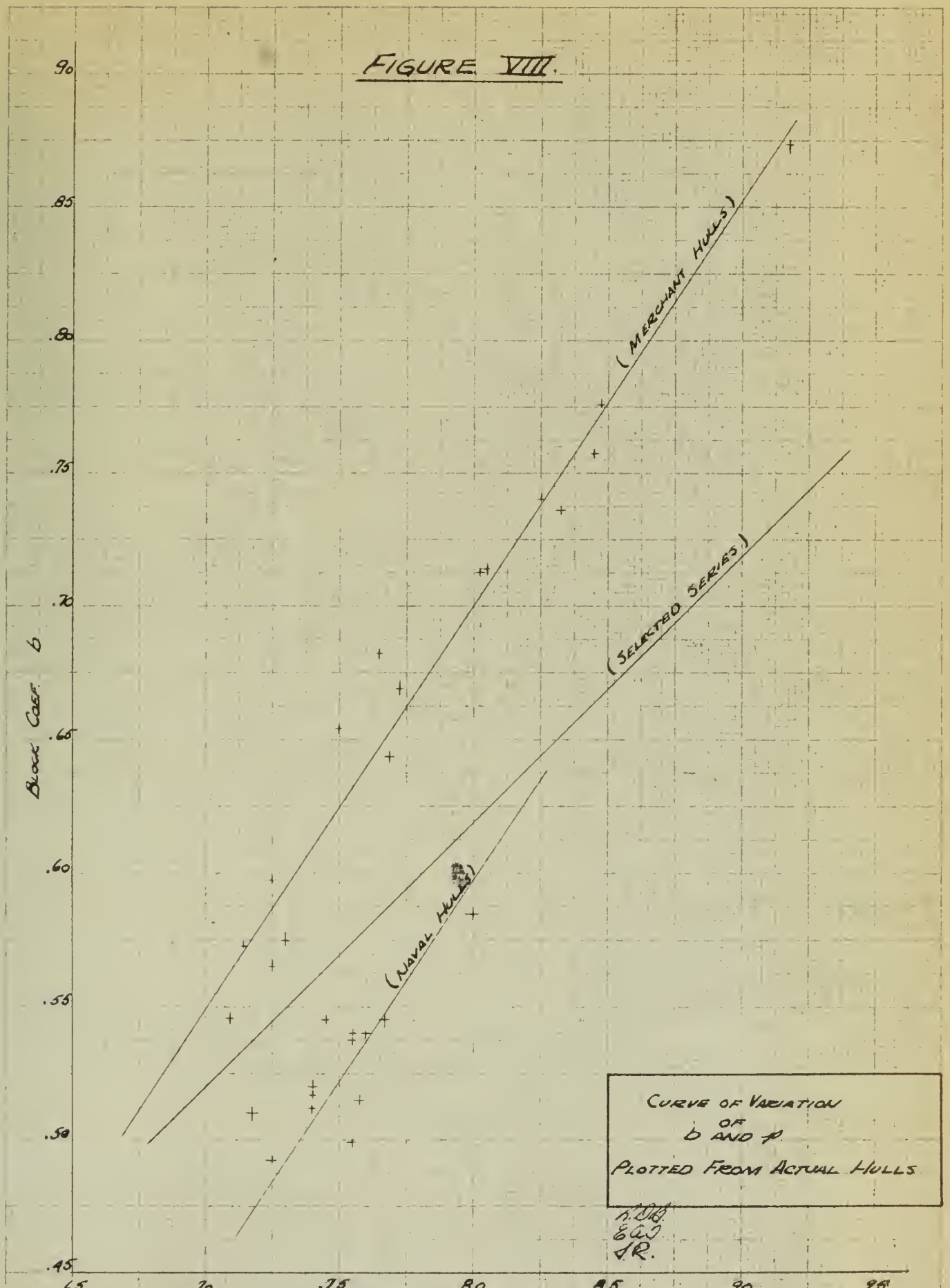
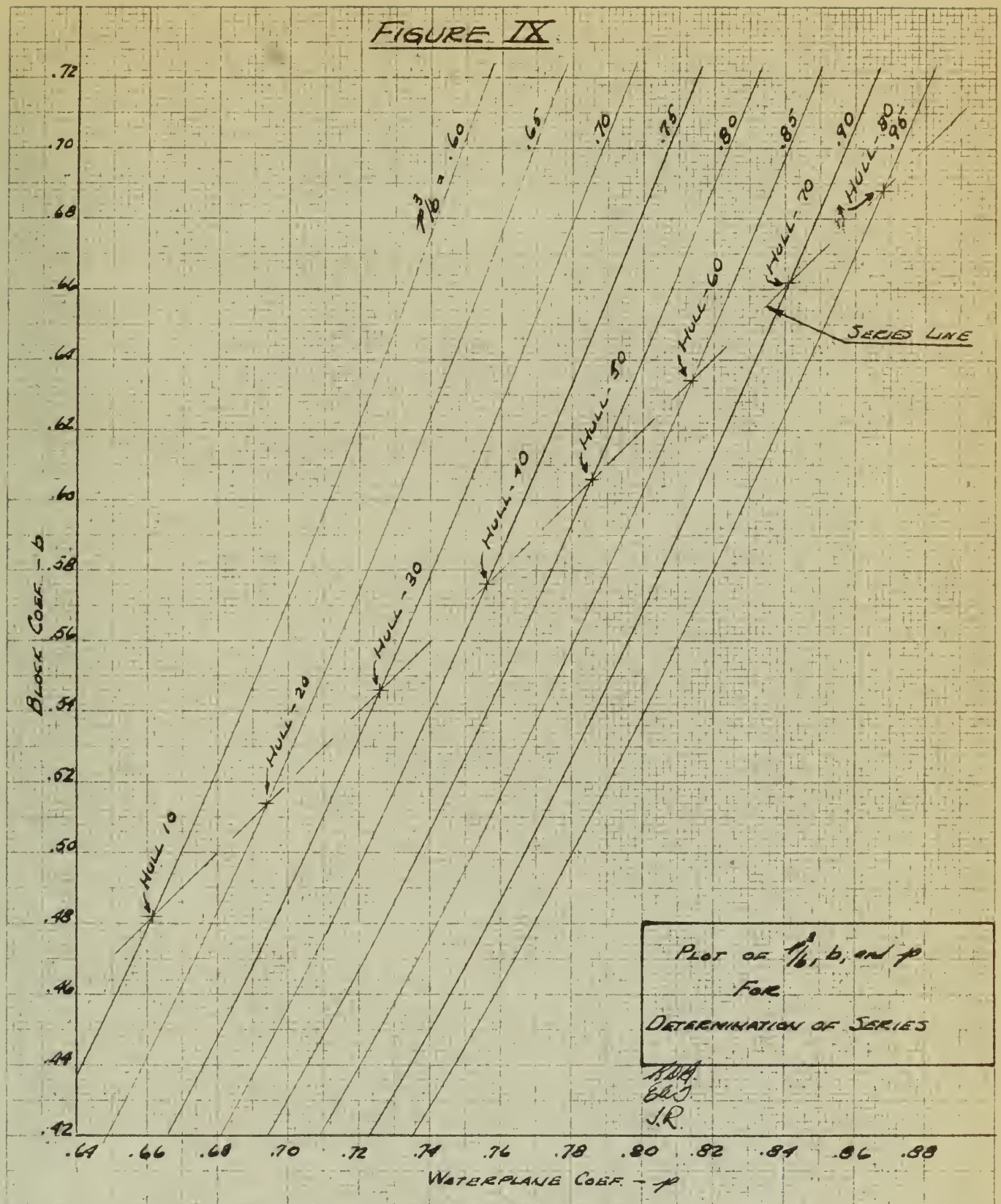

.90
.85
.80
.75
.70
.65
.60
.55
.50
.45
Block Coef. δ
(Merchant Hulls)
(Selected Series)
(Naval Hulls)
.65
.70
.75
.80
.85
.90
.95
Waterplane Coef. φ
Curve of Variation
of
δ and φ
Plotted From Actual Hulls
A.D.B.
E.C.J.
A.R.

FIGURE IX


.72
.70
.68
.66
.64
.62
.60
.58
.56
.54
.52
.50
.48
.46
.44
.42
BLOCK COEF. - b
.64
.66
.68
.70
.72
.74
.76
.78
.80
.82
.84
.86
.88
WATERPLANE COEF. - p
∇^(2/3)/L = .60
.65
.70
.75
.80
.85
.90
.95
HULL - 10
HULL - 20
HULL - 30
HULL - 40
HULL - 50
HULL - 60
HULL - 70
HULL - 80
HULL - 90
SERIES LINE
PLOT OF ∇^(2/3)/L, b, AND p
FOR
DETERMINATION OF SERIES
KDA
EJJ
JR

CURVES SHOWING VARIATION OF GZ/B WITH B/H

FOR CONSTANT D/H AND Θ VALUES.

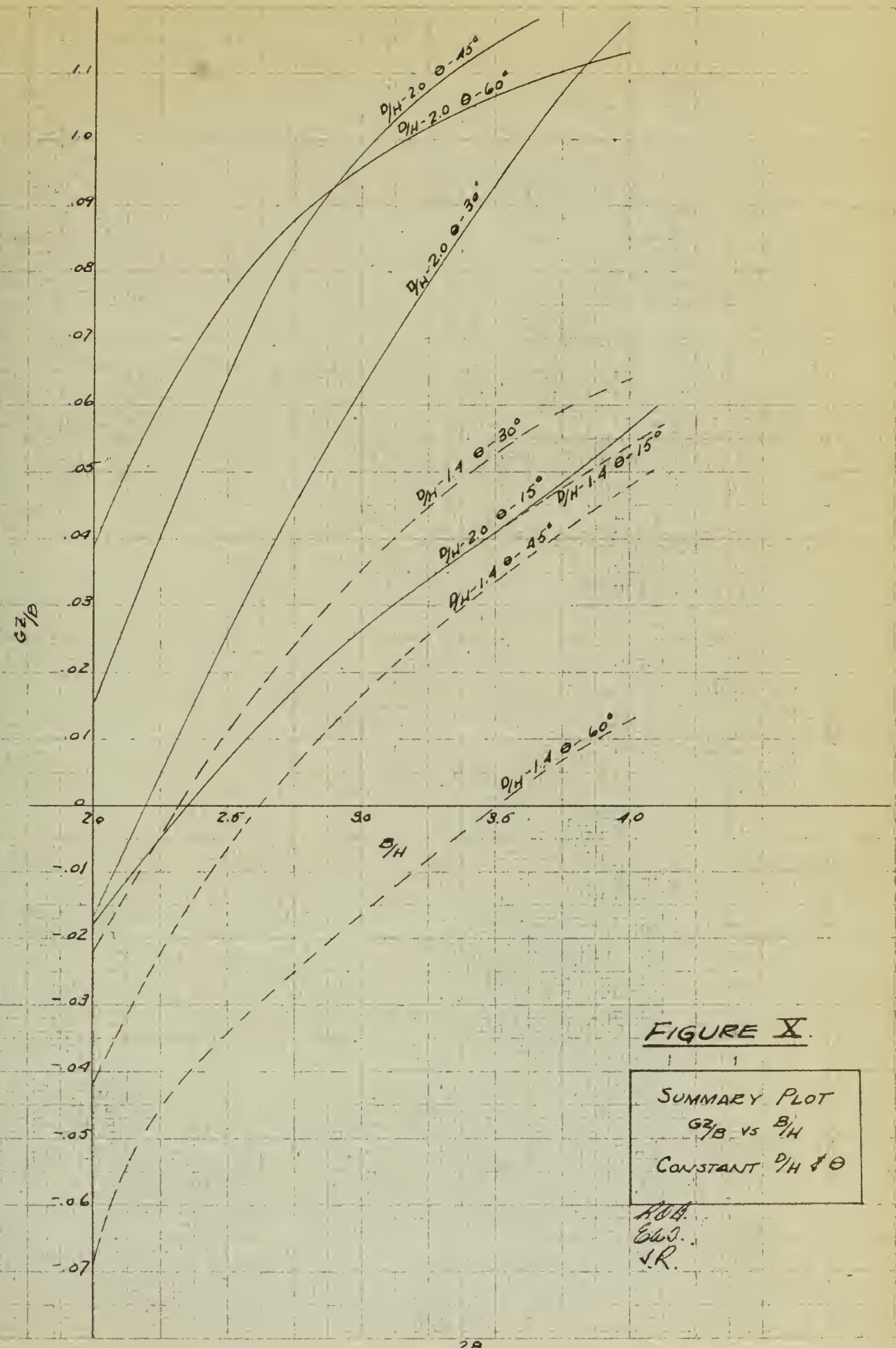


FIGURE X.

SUMMARY PLOT
GZ/B VS B/H
CONSTANT D/H & θ

A.O.A.
Edw. J.
J.R.

SUMMARY PLOT OF GZ/B vs. D/H

SHOWING EFFECT OF COEFFICIENTS.

FIGURE XI.

SUMMARY PLOT
GZ/B VS D/H
SHOWING EFFECT OF COEFFICIENTS
$B/H = 2.0$ $\theta = 15°$

HULL	b	p	n
B	.469	.77	.703
D	.469	.77	.756
F	.469	.77	.823
E	.560	.77	.982
A	.608	.77	.909
C	.608	.77	.981
G	.469	.72	.756
H	.469	.67	.756

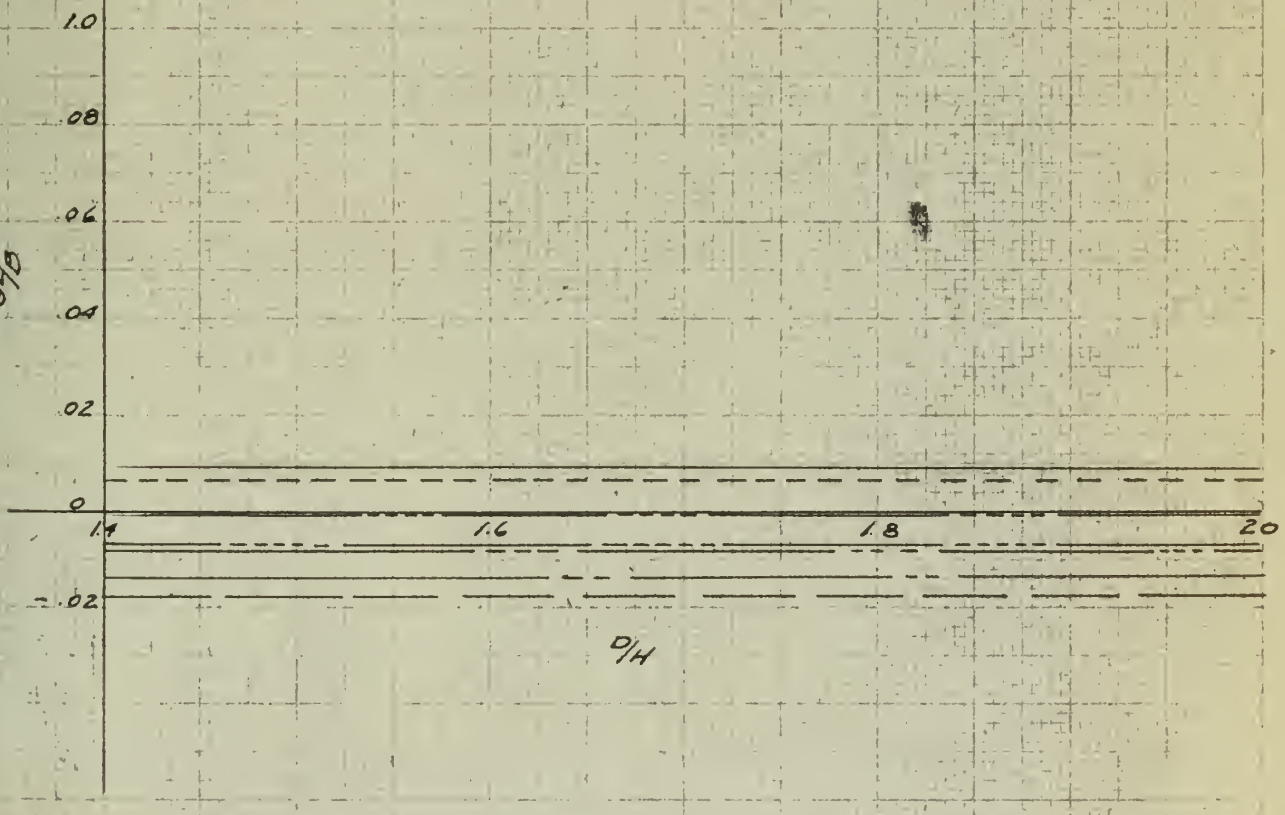


FIGURE XII.

SUMMARY PLOT
GZ/B VS D/H
SHOWING EFFECT OF
COEFFICIENTS
$B/H = 2.0$ $\theta = 30°$

HULL	b	p	m
B	.169	.77	.703
D	.169	.77	.756
F	.169	.77	.823
E	.566	.77	.982
A	.608	.77	.909
C	.608	.77	.981
G	.169	.72	.756
H	.169	.67	.756

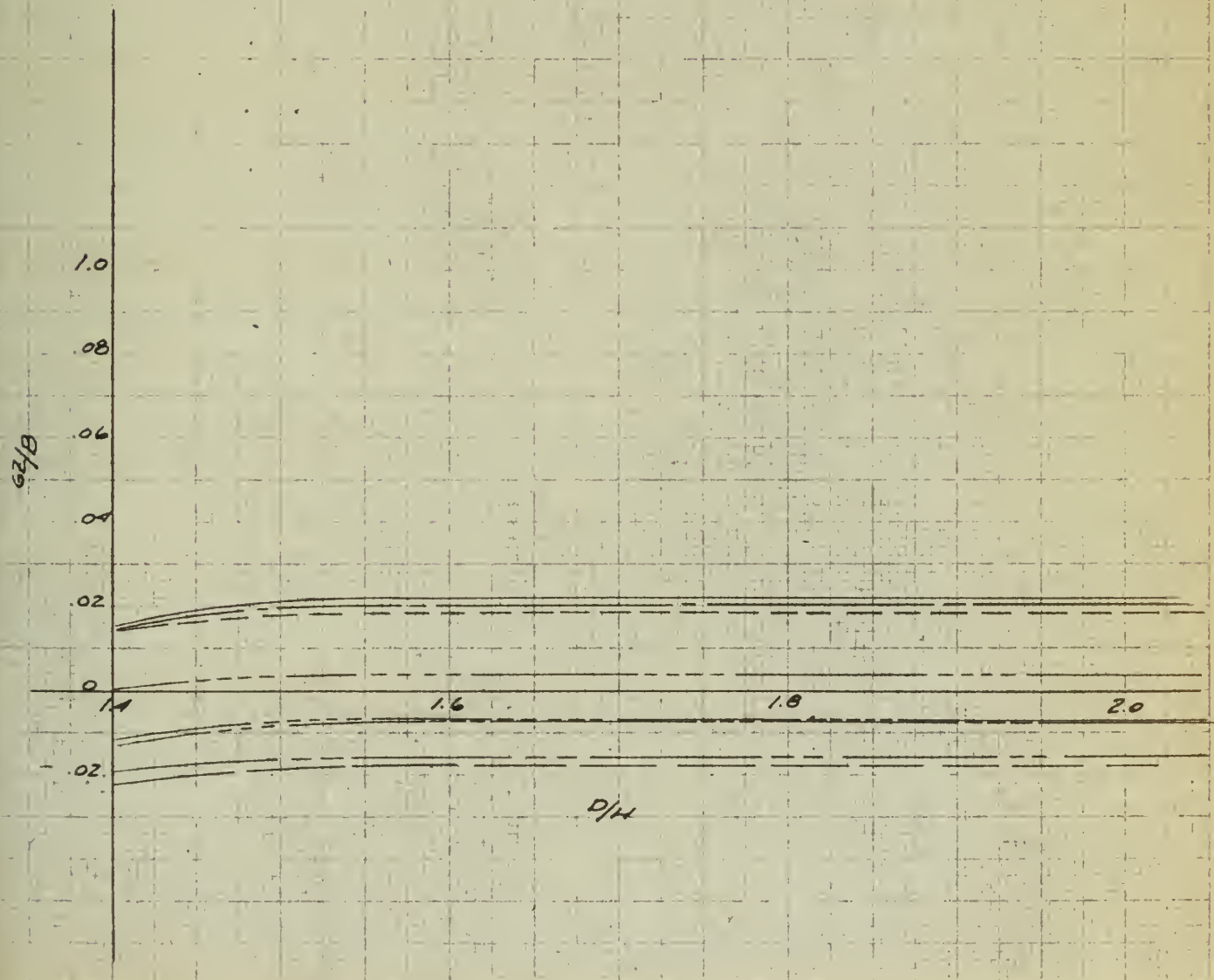


FIGURE XIII

SUMMARY PLOT
G_Z/B V.S. D/H
SHOWING EFFECT OF COEFFICIENTS
$B/H = 2.0$ $\theta = 45°$

	HULL	b	p	n
———	B	.469	.77	.703
———	D	.469	.77	.756
———	F	.469	.77	.823
———	E	.560	.77	.982
———	A	.608	.77	.909
———	C	.608	.77	.981
———	G	.469	.72	.756
———	H	.469	.67	.766

RWB
EWJ
AR

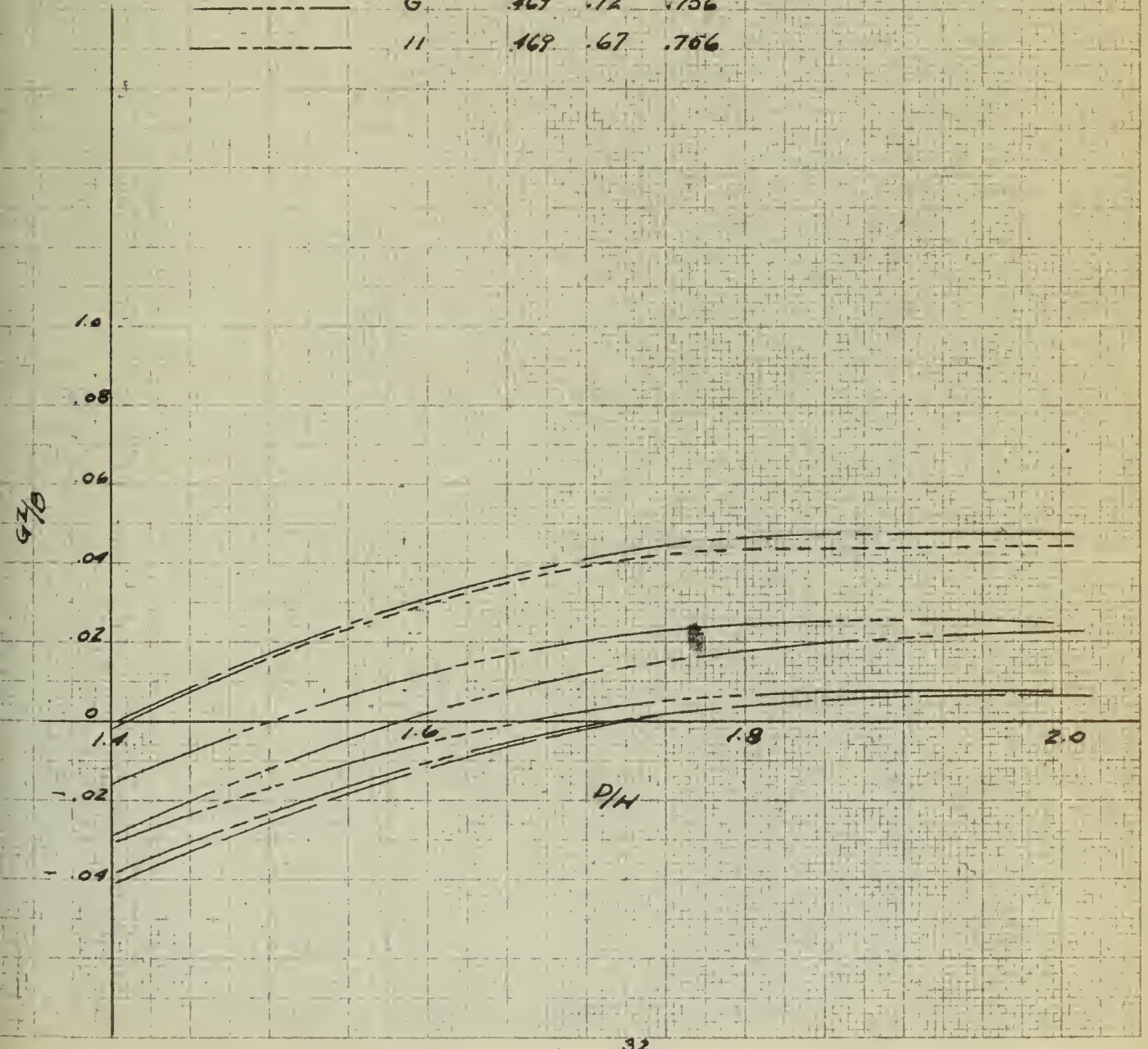
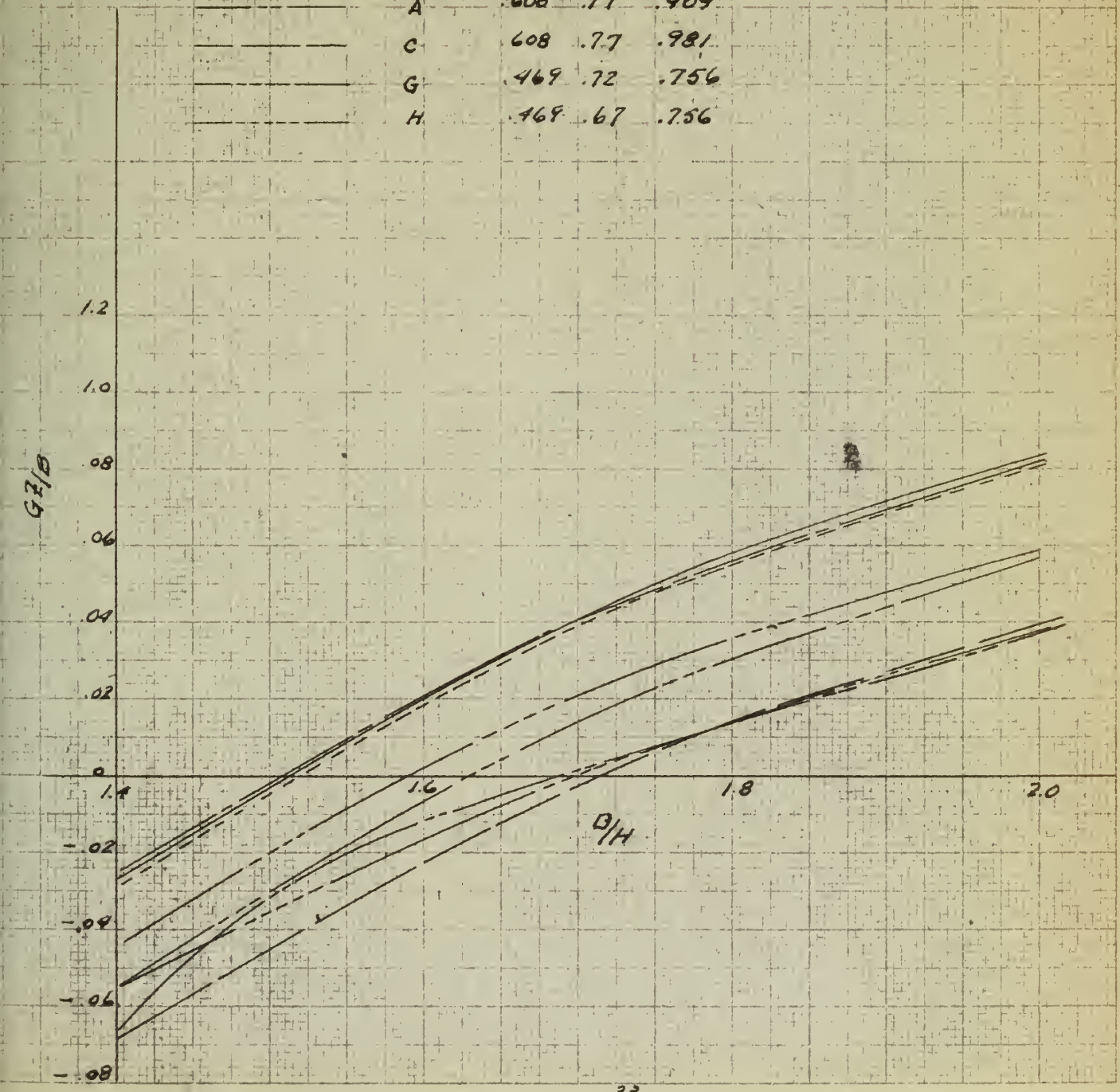


FIGURE XIV.

SUMMARY PLOT
GZ/D vs D/H
SHOWING EFFECT OF
COEFFICIENTS
B/H-2.0 Θ-60°

HULL	b	p	m.
B	.469	.77	.703
D	.469	.77	.756
F	.469	.77	.823
E	.560	.77	.982
A	.608	.77	.909
C	.608	.77	.981
G	.469	.72	.756
H	.469	.67	.756

RDA
EJJ
LR



COEFFICIENTS OF FINENESS

HULLS (20) TO (70) INCLUSIVE.

TABLE III.

COEFFICIENTS OF FINENESS

HULLS (20) TO (70) INCLUSIVE.

Fore and Aft Variation in b= ± 2%.

Hulls	20	30	(Parent) 40	50	60	70
Average						
b	.514	.546	.576	.606	.634	.660
p	.694	.726	.756	.786	.814	.840
p^3/b	.65	.70	.75	.80	.85	.90
l	.553	.587	.620	.652	.681	.710
m	.93	.93	.93	.93	.93	.93
For'd						
b	.504	.535	.565	.594	.621	.646
p	.684	.715	.745	.774	.801	.826
l	.542	.576	.603	.640	.670	.696
m	.93	.93	.93	.93	.93	.93
Aft						
b	.524	.557	.589	.618	.647	.673
p	.704	.737	.767	.798	.827	.853
l	.565	.600	.635	.665	.696	.724
m	.93	.93	.93	.93	.93	.93

TABLE OF OFFSETS

(Hulls 20 to 70 incl.)

TABLE IV.

OFFSETS - HULL 20.

Waterline

Station	.05	.10	.20	.30	.40	.50	.60	.70
1	0	0	.01	.06	.16	.33	.56	.84
2	.37	.68	1.14	1.51	1.80	2.06	2.32	2.56
3	1.20	1.99	2.94	3.42	3.76	3.98	4.13	4.23
4	2.58	3.48	4.22	4.52	4.69	4.78	4.84	4.86
5	3.23	4.00	4.55	4.76	4.86	4.92	4.95	4.97
6	2.66	3.56	4.26	4.56	4.71	4.80	4.86	4.89
7	1.03	1.78	2.77	3.39	3.81	4.07	4.24	4.36
8	.39	.72	1.25	1.62	1.93	2.19	2.44	2.71
9	0	0	.01	.07	.21	.43	.72	1.07

Station	.80	.90	1.00	1.20	1.40	1.60	1.80	2.00
1	1.16	1.49	1.83	2.24	2.48	2.64	2.76	2.85
2	2.83	3.08	3.32	3.63	3.82	3.92	4.00	4.05
3	4.30	4.35	4.39	4.44	4.51	4.57	4.64	4.70
4	4.89	4.90	4.91	4.92	4.93	4.94	4.95	4.96
5	4.98	4.99	5.00	5.00	5.00	5.00	5.00	5.00
6	4.90	4.91	4.92	4.93	4.94	4.95	4.96	4.97
7	4.42	4.45	4.48	4.54	4.58	4.61	4.64	4.66
8	2.98	3.25,	3.46	3.72	3.86	3.92	3.95	3.96
9	1.44	1.73	2.12	2.48	2.67	2.76	2.80	2.80

TABLE V.

OFFSETS - HULL 30.

Waterline

Station	.05	.10	.20	.30	.40	.50	.60	.70
1	.01	.02	.10	.22	.39	.61	.87	1.15
2	.41	.76	1.31	1.71	2.02	2.29	2.55	2.82
3	1.05	1.80	2.81	3.43	3.84	4.11	4.29	4.42
4	2.67	3.56	4.28	4.57	4.72	4.81	4.87	4.90
5	3.23	4.00	4.55	4.76	4.86	4.92	4.95	4.97
6	2.71	3.60	4.31	4.60	4.75	4.84	4.89	4.92
7	1.09	1.89	2.92	3.56	3.96	4.23	4.41	4.51
8	.51	.93	1.56	1.98	2.29	2.54	2.77	3.02
9	.01	.05	.19	.39	.63	.90	1.18	1.46

Station	.80	.90	1.00	1.20	1.40	1.60	1.80	2.00
1	1.46	1.78	2.06	2.43	2.67	2.94	2.97	3.08
2	3.10	3.38	3.64	3.80	3.97	4.08	4.18	4.27
3	4.49	4.53	4.54	4.59	4.63	4.67	4.71	4.75
4	4.92	4.93	4.93	4.93	4.93	4.93	4.93	4.93
5	4.98	4.99	5.00	5.00	5.00	5.00	5.00	5.00
6	4.93	4.94	4.95	4.95	4.95	4.95	4.95	4.95
7	4.58	4.63	4.64	4.66	4.67	4.68	4.69	4.70
8	3.29	3.56	3.72	3.93	4.04	4.09	4.11	4.11
9	1.74	2.02	2.30	2.59	2.77	2.88	2.98	3.04

TABLE VI.

OFFSETS - HULL 40.

Waterline

Station	.05	.10	.20	.30	.40	.50	.60	.70
1	.01	.05	.20	.40	.65	.92	1.21	1.49
2	.50	.91	1.54	1.97	2.29	2.56	2.80	3.06
3	1.08	1.88	2.93	3.56	3.97	4.20	4.42	4.54
4	2.69	3.59	4.31	4.60	4.76	4.85	4.91	4.93
5	3.23	4.00	4.55	4.76	4.86	4.92	4.95	4.97
6	2.70	3.61	4.32	4.62	4.77	4.85	4.92	4.95
7	1.20	2.03	3.10	3.72	4.12	4.37	4.54	4.66
8	.63	1.14	1.86	2.34	2.65	2.88	3.10	3.33
9	.03	.10	.34	.66	1.00	1.33	1.63	1.89

Station	.80	.90	1.00	1.20	1.40	1.60	1.80	2.00
1	1.78	2.07	2.38	2.78	3.02	3.18	3.26	3.35
2	3.34	3.62	3.88	4.11	4.24	4.33	4.38	4.40
3	4.63	4.65	4.67	4.72	4.75	4.77	4.79	4.80
4	4.94	4.95	4.96	4.96	4.96	4.96	4.96	4.96
5	4.98	4.99	5.00	5.00	5.00	5.00	5.00	5.00
6	4.96	4.97	4.98	4.98	4.98	4.98	4.98	4.98
7	4.71	4.75	4.77	4.80	4.80	4.80	4.80	4.80
8	3.58	3.84	4.07	4.20	4.22	4.23	4.24	4.25
9	2.12	2.34	2.53	2.77	2.93	3.05	3.12	3.20

TABLE VII.

OFFSETS - HULL 50.

Waterline

Station	.05	.10	.20	.30	.40	.50	.60	.70
1	.03	.10	.35	.68	1.04	1.39	1.69	1.96
2	.63	1.14	1.88	2.36	2.67	2.92	3.14	3.38
3	1.22	2.06	3.14	3.76	4.16	4.41	4.58	4.70
4	2.70	3.61	4.32	4.62	4.77	4.86	4.92	4.96
5	3.23	4.00	4.55	4.76	4.86	4.92	4.95	4.97
6	2.75	3.65	4.36	4.65	4.80	4.88	4.94	4.97
7	1.27	2.15	3.24	3.87	4.27	4.53	4.70	4.81
8	.71	1.28	2.10	2.61	2.94	3.17	3.38	3.62
9	.19	.38	.71	1.01	1.28	1.55	1.81	2.08

Station	.80	.90	1.00	1.20	1.40	1.60	1.80	2.00
1	2.19	2.40	2.64	2.91	3.12	3.28	3.43	3.54
2	3.64	3.90	4.14	4.27	4.39	4.46	4.50	4.53
3	4.75	4.78	4.80	4.85	4.88	4.89	4.90	4.90
4	4.97	4.98	4.98	4.98	4.98	4.98	4.98	4.98
5	4.98	4.99	5.00	5.00	5.00	5.00	5.00	5.00
6	4.98	4.99	5.00	5.00	5.00	5.00	5.00	5.00
7	4.85	4.90	4.91	4.91	4.91	4.91	4.91	4.91
8	3.88	4.14	4.37	4.43	4.49	4.50	4.50	4.50
9	2.34	2.60	2.86	3.12	3.27	3.34	3.38	3.40

TABLE VIII.

OFFSETS - HULL 60.

Waterline

Station	.05	.10	.20	.30	.40	.50	.60	.70
1	.22	.42	.77	1.07	1.34	1.61	1.86	2.11
2	.72	1.31	2.14	2.66	2.98	3.22	3.43	3.66
3	1.30	2.18	3.27	3.90	4.30	4.55	4.73	4.82
4	2.75	3.65	4.36	4.65	4.80	4.89	4.94	4.97
5	3.23	4.00	4.55	4.76	4.86	4.92	4.95	4.97
6	2.84	3.73	4.40	4.68	4.81	4.89	4.94	4.97
7	1.43	2.36	3.44	4.05	4.43	4.66	4.81	4.90
8	.80	1.44	2.34	2.91	3.22	3.47	3.66	3.90
9	.30	.57	.99	1.33	1.60	1.86	2.10	2.36

Station	.80	.90	1.00	1.20	1.40	1.60	1.80	2.00
1	2.38	2.64	2.89	3.16	3.37	3.54	3.68	3.80
2	3.92	4.13	4.30	4.50	4.61	4.67	4.69	4.71
3	4.88	4.92	4.93	4.94	4.95	4.95	4.95	4.95
4	4.98	4.99	5.00	5.00	5.00	5.00	5.00	5.00
5	4.98	4.99	5.00	5.00	5.00	5.00	5.00	5.00
6	4.98	4.99	5.00	5.00	5.00	5.00	5.00	5.00
7	4.96	4.98	5.00	5.00	5.00	5.00	5.00	5.00
8	4.15	4.41	4.52	4.58	4.60	4.61	4.62	4.63
9	2.62	2.87	3.07	3.31	3.44	3.52	3.55	3.57

TABLE IX.

OFFSETS - HULL 70.

Waterline

Station	.05	.10	.20	.30	.40	.50	.60	.70
1	.27	.51	.92	1.27	1.59	1.88	2.15	2.40
2	.77	1.35	2.18	2.74	3.18	3.51	3.80	4.06
3	1.41	2.33	3.42	4.04	4.43	4.65	4.80	4.90
4	2.86	3.74	4.41	4.68	4.80	4.88	4.94	4.97
5	3.23	4.00	4.55	4.76	4.86	4.92	4.95	4.97
6	2.96	3.81	4.45	4.70	4.83	4.88	4.94	4.97
7	1.75	2.69	3.73	4.25	4.55	4.74	4.85	4.93
8	.85	1.48	2.38	2.99	3.44	3.79	4.08	4.32
9	.37	.68	1.16	1.54	1.86	2.15	2.42	2.67

Station	.80	.90	1.00	1.20	1.40	1.60	1.80	2.00
1	2.65	2.88	3.12	3.44	3.72	3.97	4.21	4.42
2	4.26	4.41	4.51	4.64	4.72	4.77	4.79	4.81
3	4.95	4.97	5.00	5.00	5.00	5.00	5.00	5.00
4	4.99	5.00	5.00	5.00	5.00	5.00	5.00	5.00
5	4.98	4.99	5.00	5.00	5.00	5.00	5.00	5.00
6	4.99	5.00	5.00	5.00	5.00	5.00	5.00	5.00
7	4.97	4.99	5.00	5.00	5.00	5.00	5.00	5.00
8	4.52	4.71	4.86	4.90	4.94	4.95	4.96	4.96
9	2.91	3.15	3.33	3.56	3.68	3.74	3.78	3.80

TABLE X.

ORDINATES FOR CURVES OF SECTIONAL AREAS

Stations

Hull	FP & AP	1	2	3	4	5	6	7	8	9
20	0	.100	.408	.748	.957	1.00	.961	.769	.448	.144
30	0	.164	.470	.779	.963	1.00	.967	.803	.513	.208
40	0	.214	.518	.804	.967	1.00	.973	.833	.577	.272
50	0	.281	.585	.839	.974	1.00	.978	.861	.632	.327
60	0	.337	.641	.867	.979	1.00	.984	.891	.689	.385
70	0	.385	.687	.889	.983	1.00	.988	.916	.738	.436

TABLE XI.

HALF BREADTH FOR CURVES OF WATERPLANE AREA.

		Stations								
Hull	FP & AP	1	2	3	4	5	6	7	8	9
20	0	.362	.666	.878	.981	1.00	.985	.897	.702	.400
30	0	.419	.729	.908	.987	1.00	.991	.928	.760	.460
40	0	.475	.776	.934	.992	1.00	.996	.954	.815	.514
50	0	.527	.829	.961	.997	1.00	1.00	.982	.873	.572
60	0	.578	.879	.986	1.00	1.00	1.00	1.00	.925	.625
70	0	.625	.923	1.00	1.00	1.00	1.00	1.00	.973	.674

BODY PLANS FOR HULLS (20) TO (70) INCLUSIVE.

FIGURE XV

BODY PLAN
HULL SERIES 20
B/H - 2.5

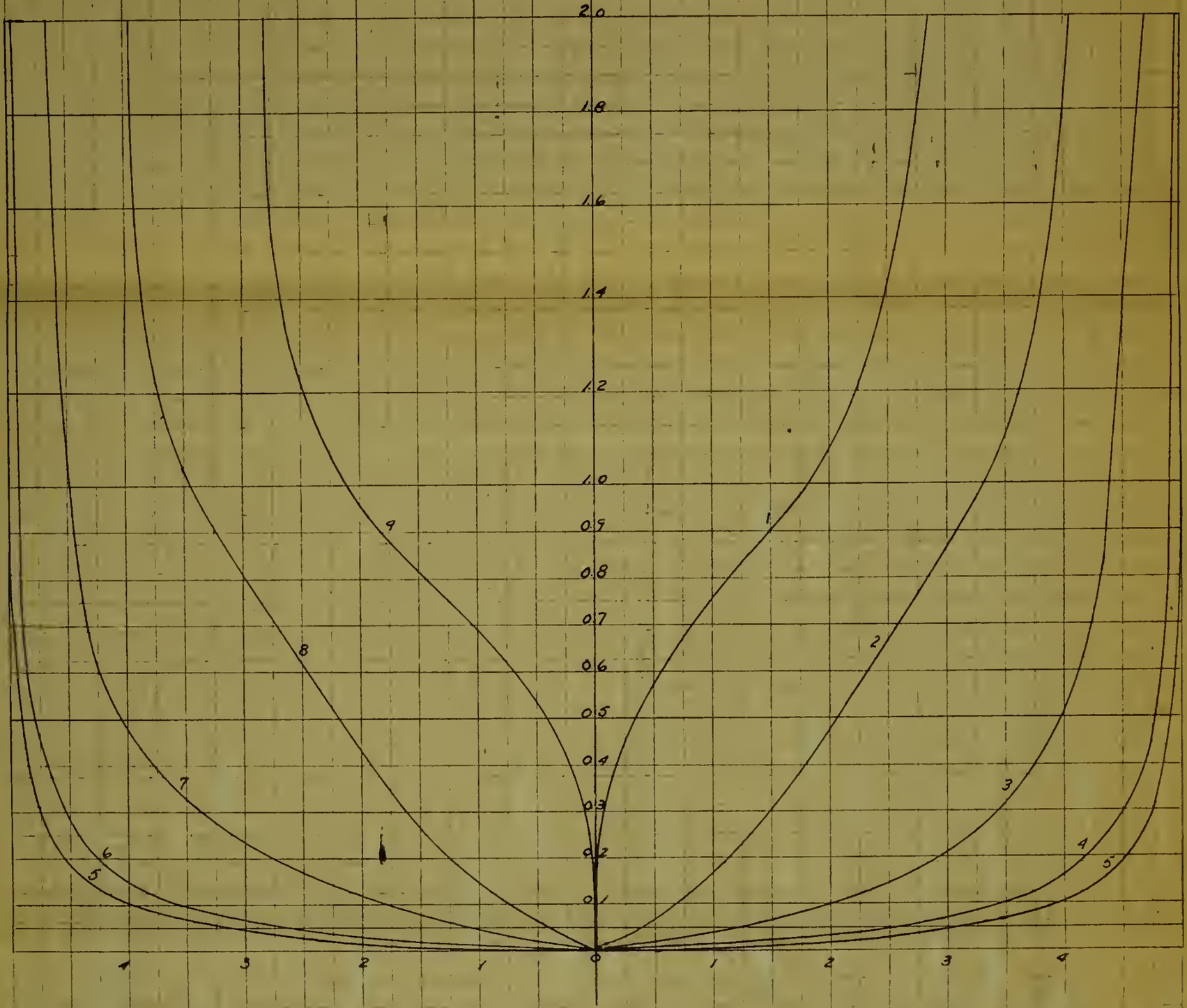


FIGURE XII

BODY PLAN
HULL SERIES 30
∇/L - 2.5

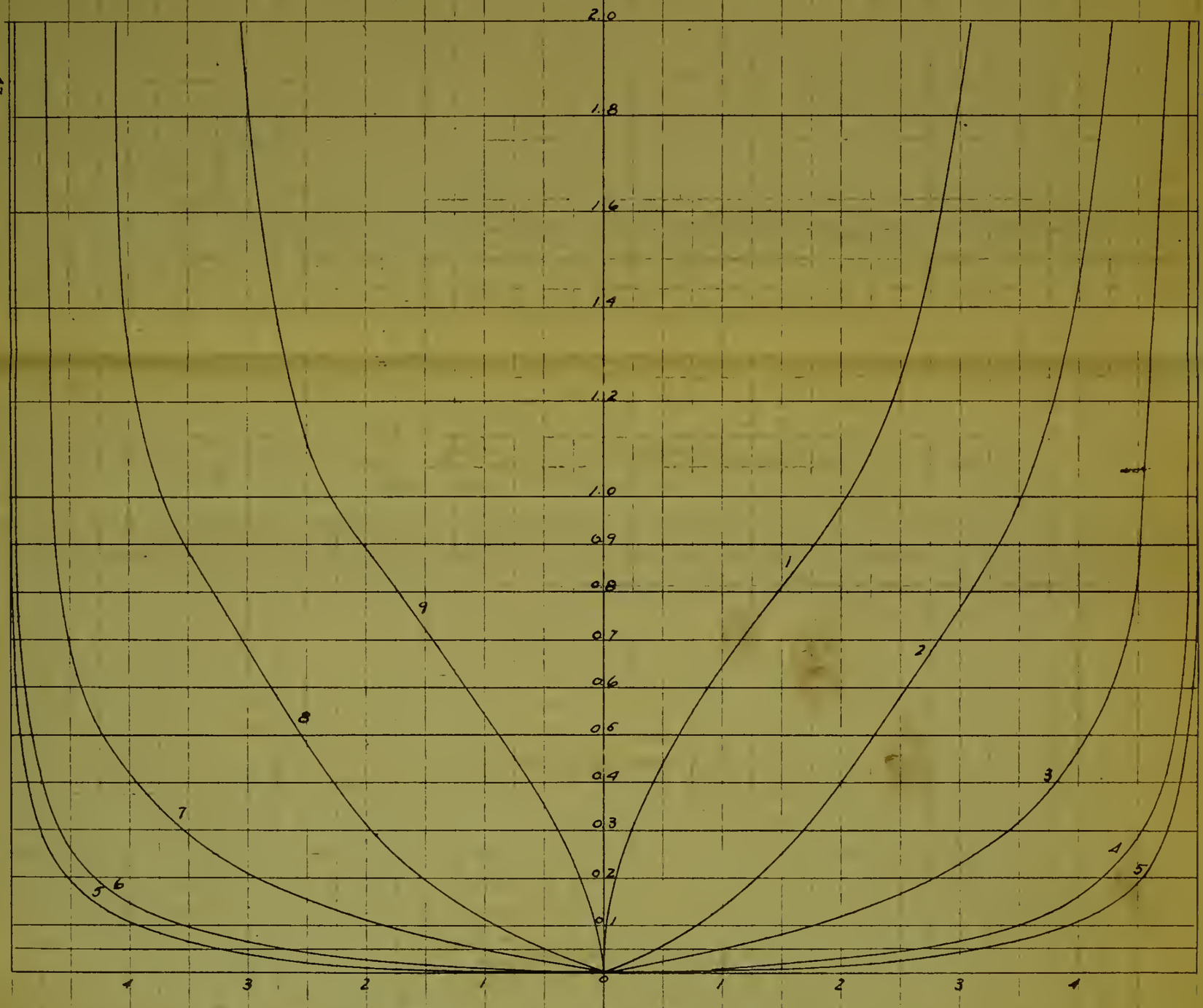


FIGURE XVII

BODY PLAN
HULL SERIES 10
$\nabla/_{\lambda^3} = 2.6$

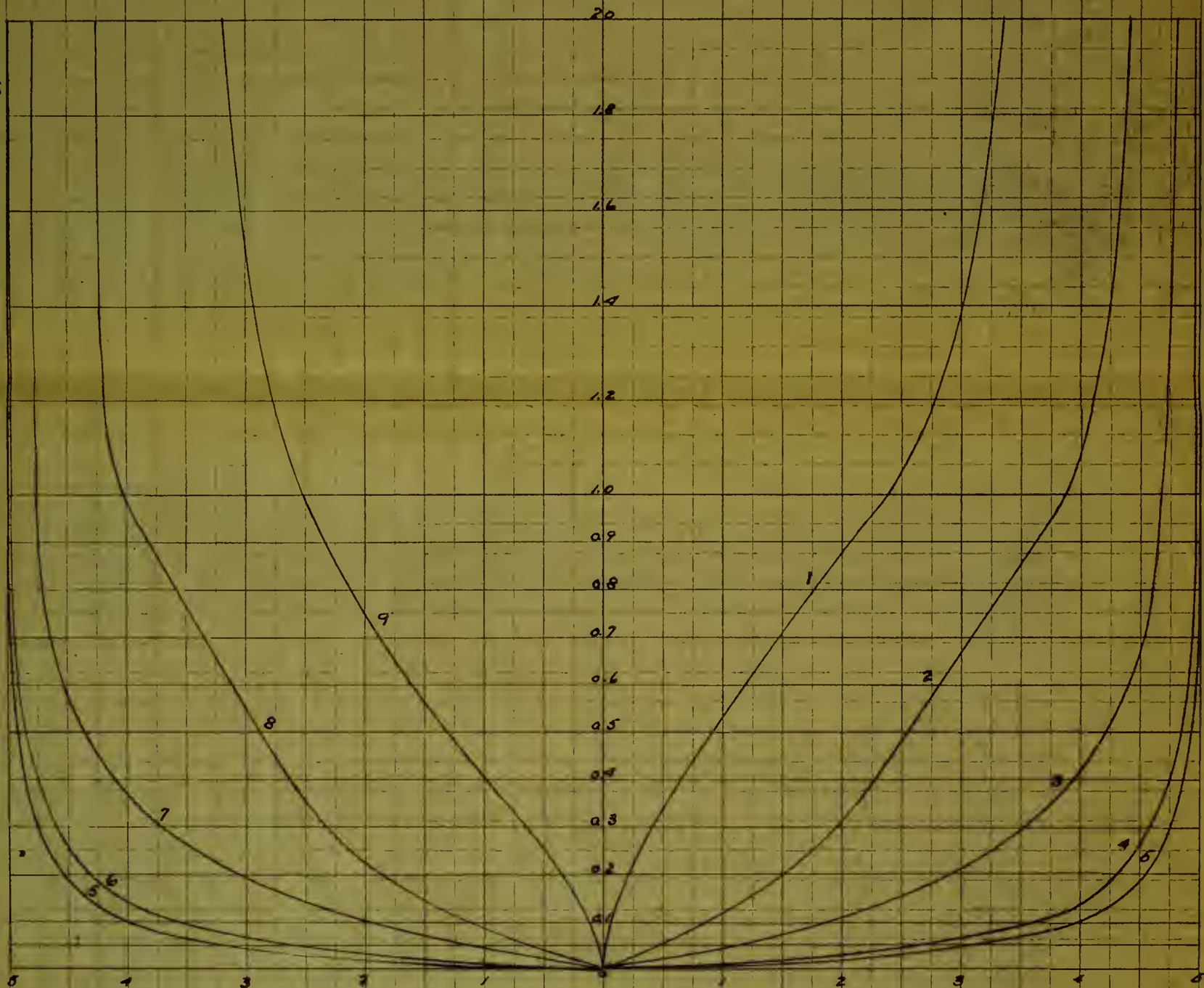


FIGURA XVIII

BODY PLAN
HULL SERIES 50
B/H - 2.5

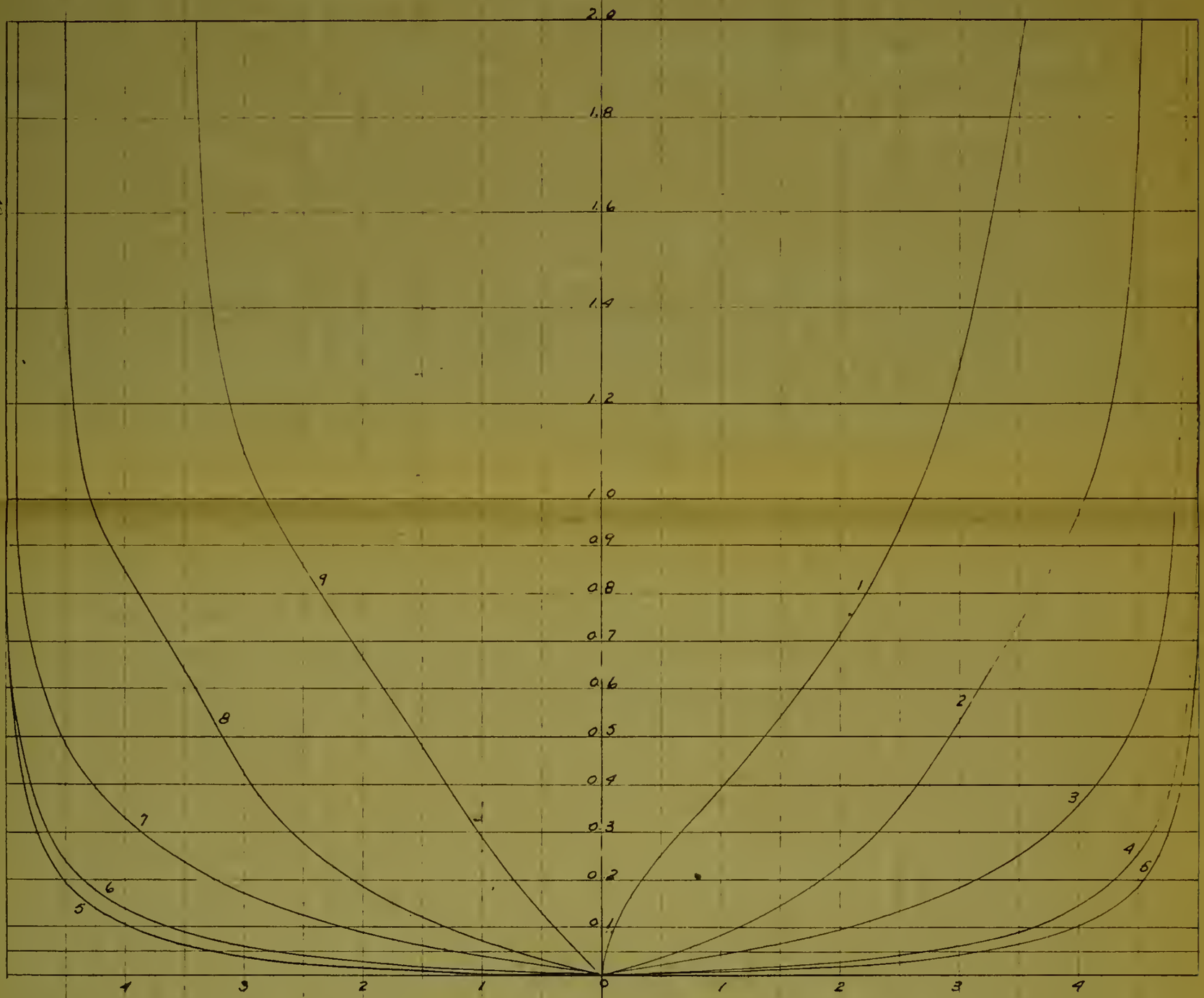


FIGURE XIX

BODY PLAN
HULL SERIES 60
$B/H = 2.5$.

ACOS
DWG
NO.

2.0 1.8 1.6 1.4 1.2 1.0 0.9 0.8 0.7 0.6 0.5 0.4 0.3 0.2 0.1 0

1 2 3 4 5

4 8 7 6 5

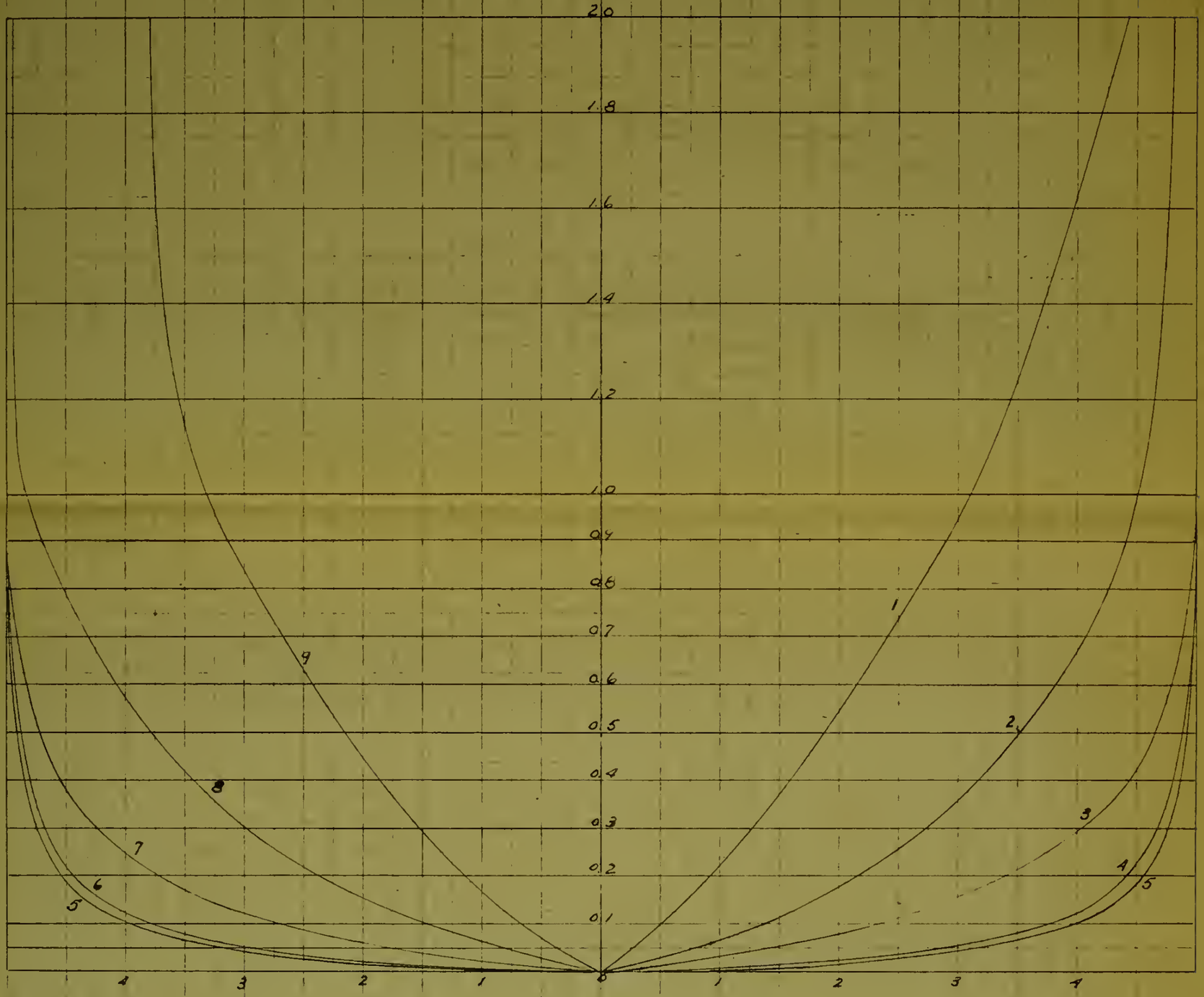
50 1

FIGURE XX

BODY PLAN

HULL SERIES - 70

B/H - 2.5



SECTIONAL AREA AND WATERPLANE CURVES

HULLS (20) TO (70) INCLUSIVE.

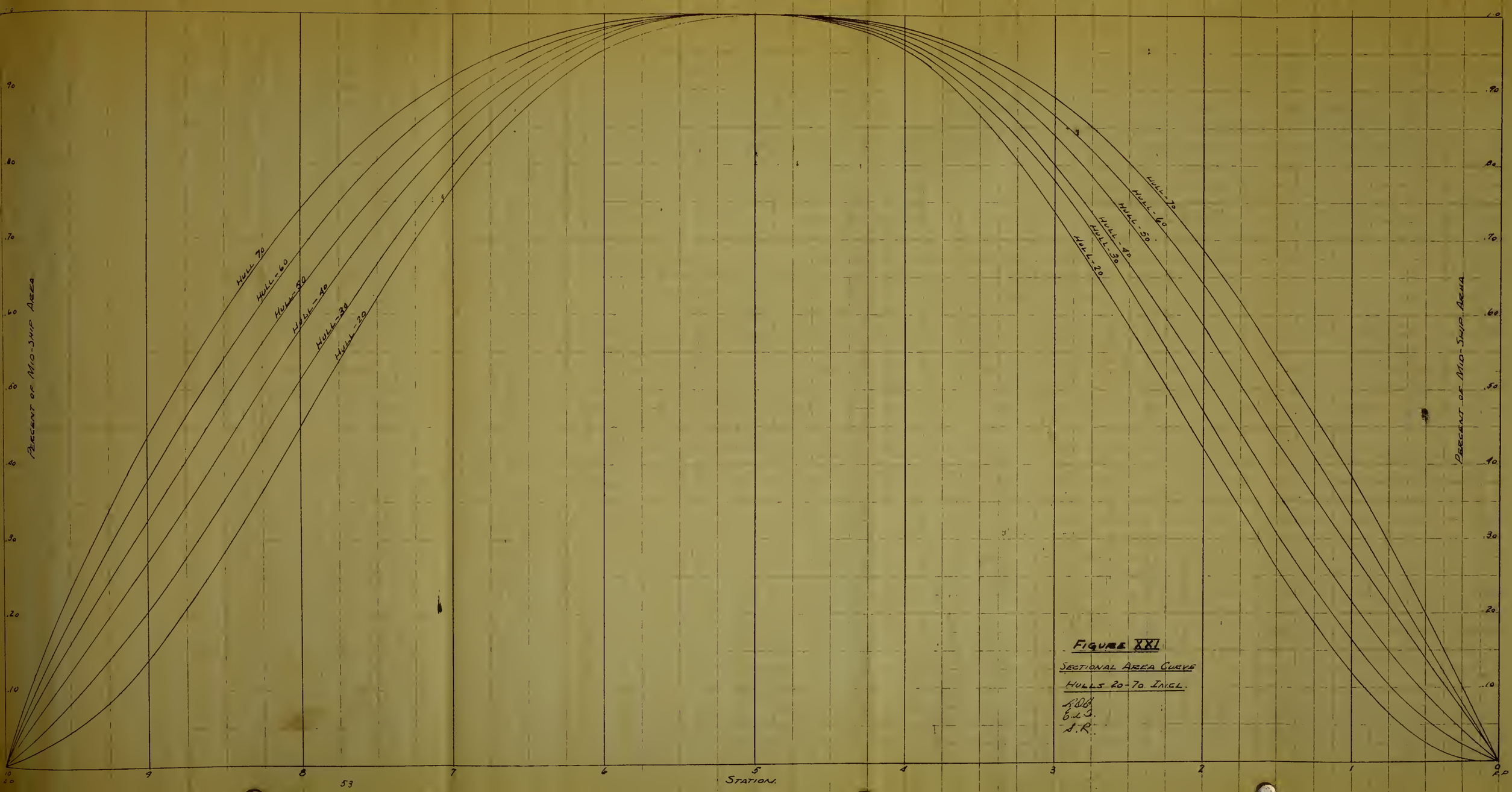


FIGURE XXI

SECTIONAL AREA CURVES

HULLS 20-70 INCL.

F.D.B.
C.L.J.
J.R.

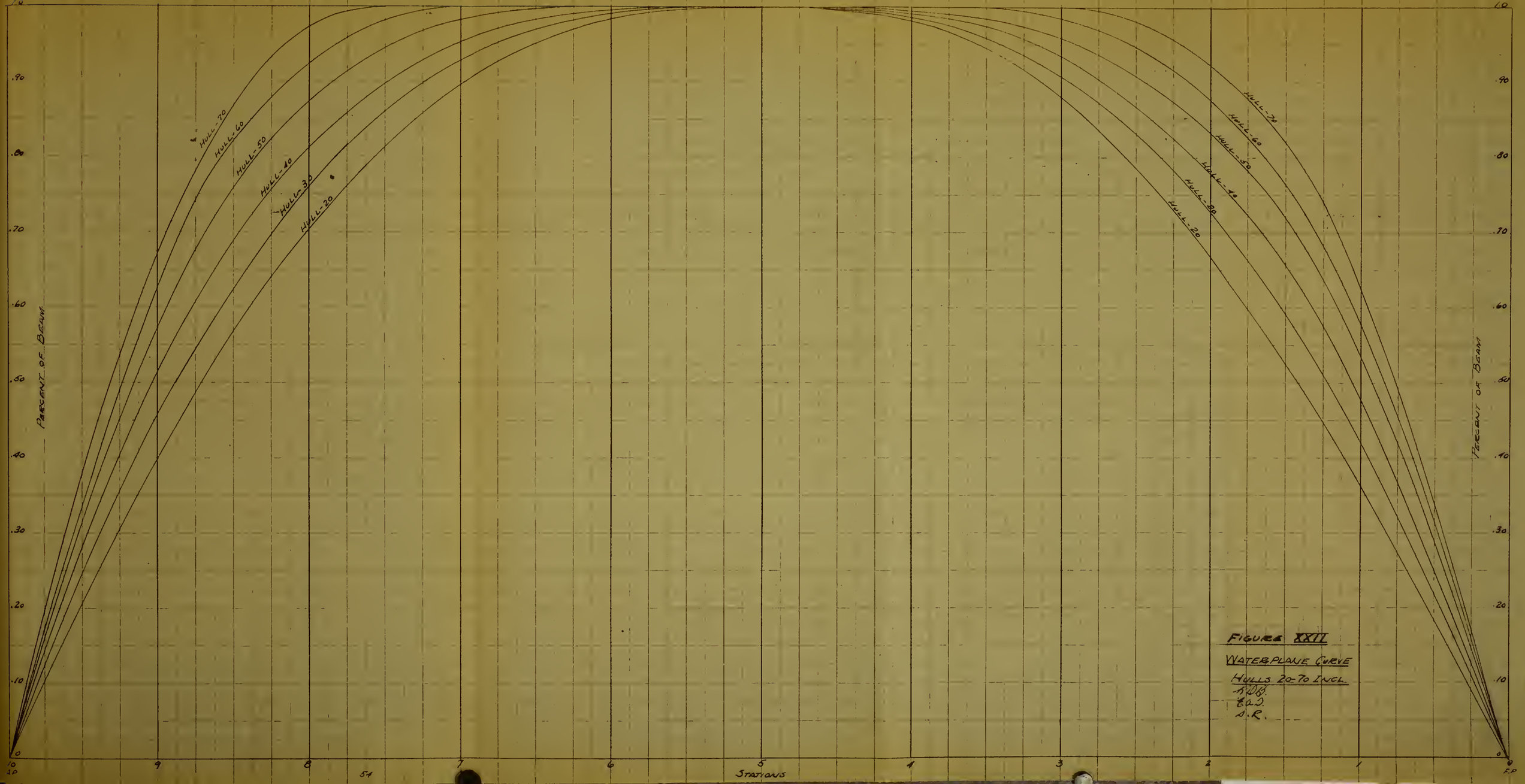


FIGURE XXII

WATERPLANE CURVE

HULLS 20-70 INCL.

B.D.B.

E.D.J.

D.R.

V. DISCUSSION OF RESULTS, RECOMMENDATIONS AND CONCLUSIONS.

The results of this investigation are presented in Section IV. in tabular and graphic form.

Tables of GZ/B for Hulls G and H, and Statical Stability Curves for these hulls, were developed for the purpose of completing the original series. (Ref. 3 and 4.)

The mathematical derivation of GZ/B, as presented in Appendix A, led to the selection of $\left(\frac{\rho^3}{b}\right)$, $\left(\frac{B}{H}\right)$ AND θ, $\left(\frac{D}{H}\right)$ as the basic parameters. The integrated values of GZ/B were plotted for Hulls A to H inclusive as shown in Fig. VII. These contours indicated a general trend which substantiated the selection of the parameters.

An attempt was also made to plot contours of GZ/B vs. ϕ and θ. ϕ represented the calculated value of GZ/B obtained from Equation (2). This was considered unsatisfactory as smooth contours were not obtained.

A study of the contours developed, Fig. VII, led to the conclusion that the deviation of the curves from the plotted points was due to the fact that the hulls developed were actually unrelated. The value of the midship section coefficient (m) had not been held constant for all vessels, which is a basic requirement for related hulls. For Hulls A to F inclusive, (p), the waterplane coefficient, had been held constant, thus stifling the effect of one of the major variables.

The inter-relationship of (p) and (b) as actually used in Merchant and Naval vessels was next investigated. For each type it was found that the variation of (b) with variation of (p) bore a 1.5 to 1 relationship. Thus a 0.10 increase in (p) is normally accompanied by a 0.15 increase in (b).

Curves of constant $\left(\frac{p^3}{b}\right)$ were superimposed upon the above plot. This indicated a normal range of $\left(\frac{p^3}{b}\right)$ from 0.60 to 0.95. A parent hull was selected with a $\left(\frac{p^3}{b}\right)$ value of 0.75. (Hull 40.) This placed the parent near the center of the field. The "family line" was taken to give an equal variation of (p) with variation of (b). This relationship must be held since a geometrically developed series has this characteristic.

A study of the effect of (B/H) was next made. Curves of variation of GZ/B with B/H for constant D/H and θ values were plotted for a typical hull. (Fig.X) This indicates that GZ/B does not vary linearly with change in (B/H). It was decided that increments of (B/H) equal to 0.25 would provide nearly linear interpolation when using the contours. The range of (B/H) necessary for the study was selected to be 2.25 to 3.75. This range is considered to cover all normal types and corresponds to the range used by Taylor for resistance purposes. (Ref. 1.)

Figures XI to XIV were plotted to provide evidence that GZ/B varies linearly with D/H. Also, it is noted that the effect on GZ/B of change in (m), for constant values of (p), is minor. A study of Results, Group IV. of Ref. 4 confirmed selection of (p) as a major variable.

Hull Family:

The parent hull selected was expanded to provide a series of six (6) related hulls through use of Taylor's Mathematical Lines (Ref. 6 and 7.) as described in Appendix B. These calculations produced ordinates for Sectional Area and Waterplane Curves, Figs. XXI and XXII. Offsets for these curves are tabulated in Tables X and XI. That a true family relationship exists can be clearly seen from the curves.

The calculations next produced offsets for body plan sections. These are tabulated in Tables IV to IX for Hulls 20 to 70 inclusive. It was found that the body plans developed using these offsets, Figures XV to XX inclusive, required very little fairing. This developed the body plan to the waterline. Development of the above-water body plans was performed in a manner to retain the proper relationship between hulls. (Appendix B)

Integration of these body plans, in the manner outlined in Reference 4, will produce values of GZ/B for various angles of inclination.

Conclusions:

Conclusions to be drawn from the investigation are as follows:

1. In any study involving the effects of change in variables it is necessary to determine the principal parameters. The parameters then must be varied in a controlled manner. With

recognition that the midship section coefficient (m) has little bearing on statical stability, it is possible to derive and utilize a geometrically ~~similar~~ related series of hulls to study statical stability.

2. Taylor's Mathematical Lines furnish a convenient and relatively quick means for development of hull forms in which the coefficients of fineness can be controlled to produce a geometrically ~~similar~~ related series.

3. Values of GZ/B obtained from integration of a proper geometrically ~~similar~~ related series can be plotted as usable contours using $\left(\frac{\Delta}{b}^3\right)$ and θ as abscissae and ordinate respectively. Contour plots would be drawn for constant values of B/H and D/H.

Recommendations:

1. An integration of Hulls 20 to 70 inclusive should be performed and resulting values of GZ/B be plotted as contours as previously described.

2. During the integration the values of B/H should be varied in increments of 0.25 with the range from 2.25 to 3.75.

3. During integration, angles of inclination should be taken as follows:

0, 15, 30, 40, 50, 60, 70, 80 degrees.

4. (D/H) values should be taken as

1.40, 1.60, 1.80, 2.00.

5. If, when plotting contours, it is found necessary to develop hulls with intermediate values of $\left(\frac{\Delta}{b}^3\right)$, this should

be done in accordance with the method described in Aprendix B. The hulls are numbered using a decimal system to allow freedom in interposing additional hulls.

6. It is recognized that flare and shear will effect statical stability. In this investigation no consideration has been given to shear, but reasonable flare has been introduced in the development of the hulls. It is recommended that a separate study be made of the effects of flare and shear, and that correction curves for application to the basic contours be prepared.

7. When contours are finally plotted, Statical Stability Curves should be developed for hulls of various types to test the accuracy of the developed curves when compared with the actual Statical Stability Curves of these vessels.

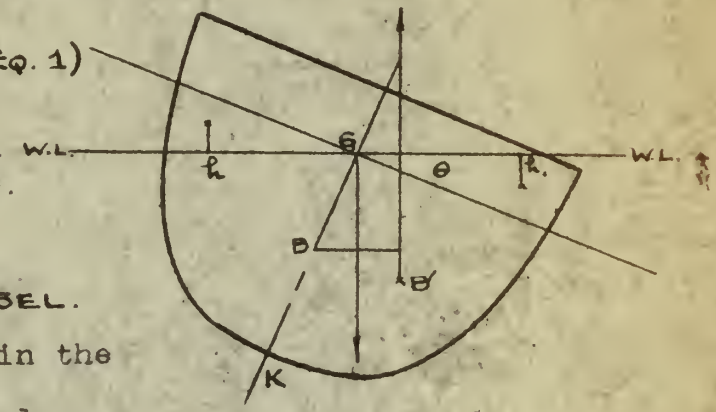
APPENDIX

APPENDIX A.

MATHEMATICAL ANALYSIS OF (GZ/B).

In order to determine the basic parameters effecting the statical stability of a vessel a mathematical analysis of (GZ/B) was developed. The development was based on Atwood's equation for righting arms (Reference 8).

$$\overline{GZ} = \frac{v \times \overline{hh_1}}{V} - \overline{BG} \sin\theta \quad \text{(Eq. 1)}$$



v = Volume of one wedge.

V = Total volume of displacement of vessel.

Other symbols are as indicated in the sketch and in the Table of Symbols.

$$v \cong \left(\frac{\rho B}{2}\right)^2 \tan\theta \left(\frac{1}{2}\right) L.$$

$$V = b.L.B.H.$$

$$\overline{GZ} \cong \frac{\rho^2 B.(\overline{hh_1}) \tan\theta}{8\, b H} - \overline{BG} \sin\theta.$$

$$\overline{hh_1} \cong 2\left(\frac{\rho B}{2}\right)\cos\theta\left(\frac{2}{3}\right) = \left(\frac{2}{3}\rho B \cos\theta\right)$$

$$\left(\frac{\overline{GZ}}{B}\right) \cong \left[\frac{1}{12}\left(\frac{\rho^3}{b}\right)\left(\frac{B}{H}\right) - \frac{\overline{BG}}{B}\right] \sin\theta \quad \text{(Eq. 2.)}$$

Moorish's approximate formula for the distance of B above the base line, Equation 3, was used. (Reference 8.)

$$\overline{KB} = \frac{1}{3}\left(\frac{5H}{2} - \frac{V}{A}\right) \quad \text{(Eq. 3.)}$$

V, in this case, is the volume of displacement at mean draft H. A is the area of the corresponding waterline.

THUS - $V = 6\,L.B.H \qquad A = p.L.B.$

Substitution in Equation 3 gives:

$$\overline{KB} = H\left(\frac{5}{6} - \frac{b}{3p}\right)$$

$$\overline{BG} = \overline{KG} - \overline{KB}. \qquad \text{(EQ. 4.)}$$

For this investigation KG is taken as H.

THEN - $$\overline{BG} = H - \overline{KB} = H\left(\frac{1}{6} + \frac{b}{3p}\right)$$

AND - $$\frac{\overline{BG}}{B} = \frac{H}{B}\left(\frac{1}{6} + \frac{b}{3p}\right)$$

SUBSTITUTING IN EQUATION 2:

$$\left(\frac{GZ}{B}\right) = \left[\frac{1}{12}\left(\frac{p^3}{b}\right)\left(\frac{B}{H}\right) - \left(\frac{H}{B}\right)\left(\frac{p + zb}{6p}\right)\right] \sin\Theta \qquad \text{(EQ. 5.)}$$

Factors influencing initial stability were next considered.

$\overline{BM}$ = TRANSVERSE METACENTRIC RADIUS = $\left(\frac{I}{V}\right)$

$$I = \frac{2}{3}\int_0^L y^3\,dx.$$

CONSIDERING A MEAN RECTANGLE -

$y_{MEAN} = pB$ = CONSTANT.

$$I = f(p^3B^3, L) \qquad V = 6LBH.$$

$$\overline{BM} = \frac{f(p^3B^3, L)}{f(6LBH)}$$

$$\frac{\overline{BM}}{B} = \frac{f(p^3B^3, L)}{f(6LB^2H)} = f\left(\frac{p^3}{b}\right)\left(\frac{B}{H}\right) \qquad \text{(EQ. 6.)}$$

Appearance of the parameters $\left(\frac{\nabla}{b^3}\right)$ and $\left(\frac{B}{H}\right)$ in Equations (5) and (6) indicates the importance of these in the control of the magnitude of the righting arms. In the derivation of Atwood's expression the assumption is made that the immersed and emerged wedges are of equal volume. Thus, the effects of (D/H) are not included in the derivation and this variable should be added to the list of parameters.

In addition, attempts were made to determine equations which would develop curves representing sections having half-breadth $\left(\frac{\nabla B}{2}\right)$ at draft (H) and having the additional quality of including an area whose integration over the length of the vessel would develop the total volume of the vessel. The section would then represent a mean of all sections of the vessel. The original intention was to develop an equation which would be possible of integration for values of θ to give righting moments of the emerged wedges.

While an equation allowing integration for values of θ was not developed, an interesting development for values of $\left(\frac{\overline{KB}}{H}\right)$ resulted.

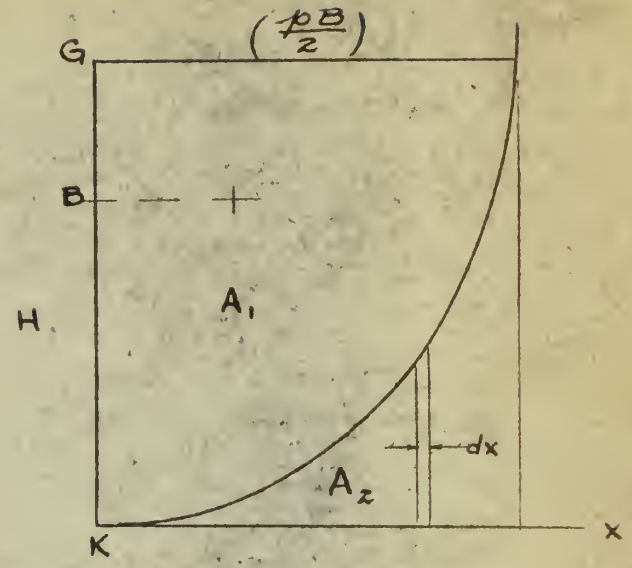
THE EXPONENTIAL FORM

$y = a \cdot x^n$ WAS USED.

THE ORIGIN IS AT K.

TO SATISFY THE BOUNDARY CONDITIONS WE FIND —

$$a = \frac{H}{\left(\frac{p B}{2}\right)^n}$$



THE AREA $A_2 = \int_0^{\frac{pB}{2}} y \cdot dx$

$$A_2 = \left[\frac{H}{\left(\frac{pB}{2}\right)^n} \cdot \frac{x^{n+1}}{n+1} \right]_0^{\frac{pB}{2}} = \left[\frac{H\, p\, B}{2(n+1)} \right]$$

$$A_1 = \left(\frac{p B H}{2} - A_2 \right) = \left(b \cdot H \cdot \frac{B}{2} \right)$$

$$A_2 = \left(\frac{p B H}{2} - \frac{b \cdot H \cdot B}{2} \right) = (p - b)\left(\frac{B}{2} \cdot H \right)$$

SETTING: $$(p - b)\left(\frac{B}{2} \cdot H \right) = \frac{H \cdot p \cdot B}{2(n+1)}$$

WE FIND: $$(p - b) = \left(\frac{p}{n+1} \right)$$

FROM WHICH: $$n = \left[\frac{b}{p - b} \right] \qquad \text{(EQ. 7.)}$$

THE DEVELOPMENT OF $\left(\frac{\overline{KB}}{H}\right)$ WAS NEXT PERFORMED.

TAKING MOMENTS ABOUT THE BASELINE:

$$\overline{KB}\cdot A_1 + \bar{y}\,A_2 = \left(\frac{pBH}{2}\right)\left(\frac{H}{2}\right)$$

$$\bar{y}\cdot A_2 = \frac{1}{2}\int_0^{\frac{pB}{2}} y^2\,dx = \left[\frac{H^2\cdot\frac{pB}{2}}{2(2n+1)}\right]$$

$$\overline{KB} = \left[\frac{\left(\frac{pB}{2}\right)\left(\frac{H^2}{2}\right) - \bar{y}\,A_2}{\left(\frac{pB}{2}\right)(H) - A_2}\right] = \left[\frac{\left(\frac{pB}{2}\right)\left(\frac{H^2}{2}\right) - \left(\frac{H^2}{2}\right)\left(\frac{\frac{pB}{2}}{2n+1}\right)}{\left(\frac{pB}{2}\right)(H) - \frac{(H)\left(\frac{pB}{2}\right)}{(n+1)}}\right]$$

$$\overline{KB} = \frac{H}{2}\left[\frac{1 - \frac{1}{2n+1}}{1 - \frac{1}{n+1}}\right] = H\left(\frac{n+1}{2n+1}\right)$$

THEREFORE – $\quad \frac{\overline{KB}}{H} = \left(\frac{n+1}{2n+1}\right)$

SUBSTITUTING – $\quad n = \left(\frac{b}{p-b}\right)$

WE FIND – $\quad \frac{\overline{KB}}{H} = \left(\frac{p}{b+p}\right)$ (EQ. 8.)

ALSO – $\quad \frac{\overline{BG}}{H} = \left(\frac{b}{b+p}\right)$ (EQ. 9.)

SUBSTITUTION IN EQUATION (2) GIVES –

$$\left(\frac{\overline{GZ}}{B}\right) = \left[\frac{1}{12}\left(\frac{p^3}{b}\right)\left(\frac{B}{H}\right) - \left(\frac{H}{B}\right)\left(\frac{b}{b+p}\right)\right]\sin\theta \qquad \text{(EQ. 10)}$$

Calculation of KB/H using Moorish's Formula, Equation 4, and the Exponential form, Equation 8, led to the following comparison with the actual integrated values for Hulls A to H inclusive.

VALUES OF KB/H

Hull	p	b	B/H 2.0	2.5	3.0	3.5	4.0	Moorish	ax^n
A	.77	.608						.5730	.5580
B	.77	.469						.6330	.6200
C	.77	.608	.5490	.5550	.5680	.5530	.5420	.5730	.5580
D	.77	.469	.6298	.6320	.6400	.6320	.6400	.6330	.6200
E	.77	.560	.5718	.5700	.5700	.5650	.5800	.5930	.5780
F	.77	.469	.6216	.6220	.6260	.6150	.6220	.6330	.6200
G	.72	.469	.6156				.6140	.6190	.6050
H	.67	.469	.6062				.6000	.6040	.5870

The integrated values were developed as outlined in the Procedure Section of Reference 4.

APPENDIX B.

SPECIFIC APPLICATION OF TAYLOR'S MATHEMATICAL LINES.

Taylor's Mathematical Lines were used in the development of the Series of related hulls. As the general application of the method is completely described in Reference (6), only those features of the method directly effecting the development of the hulls will be discussed. The discussion will follow the chronological use of the development.

Development of the Sectional Area Curve:

At this stage of the development the fineness coefficients (b), (p), (l), and (m) are known. From a study of the basic reference and of Appendix A of Reference 3, use of the following equations was justified.

$$\alpha_0 = (40 - 60\,l) \qquad \text{(EQ. 11.)}$$

$$t = \left(10l - 5 - \frac{\alpha_0}{12}\right) \qquad \text{(EQ. 12.)}$$

α_0 may be either positive or negative. However, it is obvious that the values of (t) must always be greater than zero for a related series. In the development of the series, Hull 20 had such fine coefficients as to result in a negative (t). In this case the ordinates of the Sectional Area Curve were obtained from graphical transformation of the Sectional Area Curve of Hull 30.

α_1 was taken as zero in all calculations. This is considered consistent with the nature of the curves at the midship section.

The above decisions made it possible to compute the ordinates of the Sectional Area Curves of the hulls. The form used and a sample calculation for the Parent Hull (40) is included in the Appendix, Table XII.

Development of the Waterplane Curves:

The half-breadths of the waterplane curves were calculated in exactly the same manner as the ordinates of the Sectional Area Curve. Values of (p), however, are in this case substituted for (l) as shown in the Equations (11) and (12).

Development of the Constants for Sections:

The first step in the determination of the Constants for Sections was establishment of the method of determination of flare (f) and the Dead Rise Reciprocal (R). The Section Coefficient, m_s, is defined as $\left[\frac{A_m}{y_b}\right]$. Equation (10), page 47, of Reference (6) relates (f) and (m_s).

$$(m_s - 0.50) = -(f-1)\left(\frac{10x^2 - 10x + 3}{60x^2 - 80x + 30}\right)$$

X, as used in this equation, is the point in the curve at which inflection occurs. The authors considered that to have the inflection at the waterline would yield curves most nearly approaching the nature of normal ship sections. Thus, substituting X = 1 in the above equation, we find:

$$f = \left[\frac{8 - 10\,m_s}{3}\right] \qquad (Eq.\ 13.)$$

It is seen that for values of m_s greater than 0.80, the flare, (f), must be zero.

Reference (6) gives the following equations for m_0, the Section Coefficient with zero flare, and (R).

$$m_0 = \left[\frac{m_s - \frac{f}{2}}{1-f}\right] \qquad \text{(EQ. 14.)}$$

$$R = \left[\frac{1 - f(1-L)}{L}\right] \qquad \text{(EQ. 15.)}$$

Figure 15 of Reference (6) presents a curve of (L) plotted against m_0. With the above information the Constants for Sections can be calculated. The form used and a sample calculation is included, Table XIV.

Hyperbolic Sections:

For Hyperbolic Sections

$$y_s = f_x + (1-f)(\phi x) \qquad \text{(EQ. 16.)}$$

In this case x represents the distance from the baseline to the waterline concerned, and (ϕx) is obtained from the contours plotted in Figure 15 of Reference (6). For the hulls developed for integration the beam is 10 inches. In this case

$$Y = (5 \cdot y_b \cdot y_s) \qquad \text{(EQ. 17.)}$$

Table XV of the Appendix shows the form developed for ease in calculation of this type of section. The Hyperbolic type of section was used in those cases where m_s was greater than 0.72.

Fourth-Power Sections:

For fine sections in which the value of m_3 was less than 0.72 the Fourth-Power type of Section was used. In this case

$$y_5 = (Y + m_3 M + f F + RL) \qquad \text{(EQ. 18.)}$$

(M), (F), (L), and (Y) are constants. The calculation then only involves evaluation of the formula. The constants used are taken from Table III of Reference (6). Again, as in the Hyperbolic Sections,

$$Y = (5 \cdot y_6 \cdot y_5)$$

Figure XVI of the Appendix shows the form used and a sample calculation.

General:

In the development of the equations used for preparation of the related series, the authors considered it imperative to provide a purely mathematical method. Thus, there would be no requirement for the use of arbitrary selection. The development of the body plans below the water line fulfills this objective. However, in the development of the body plan above the waterline, decision regarding the amount of flare had to be made. The above-water body plan was drawn for Hull 40, the Parent Hull, and through graphical methods was transformed to complete the body plans of the other hulls of the series. The waterplane was drawn at the 2.0 waterline and faired with the body plan. This curve

was superimposed on the waterline curves drawn for the 1.0 waterline. At any section a horizontal line was drawn at the height of the 1.0 waterline of Hull 40, and a similar horizontal line drawn at the height of the 1.0 waterline of the Hull concerned. A vertical line is next drawn through the intersection of the first horizontal line and the 2.0 waterline for Hull 40. Intersection of this line and the second horizontal line locates a point on the 2.0 waterplane of the Hull concerned. Development in this manner continues the related nature of the hulls.

TABULAR FORMS AND SAMPLE CALCULATIONS USING TAYLOR'S MATHEMATICAL LINES.

TABLE XII

HULL SERIES - 40 SECTIONAL AREAS

COEFFICIENTS

$b = .576$

$p = .756$

$\ell = .620$

$m = .930$

PARAMETERS

FWD	AFT.
$b = .712$	$b = 1.192$
$\alpha_1 = 0$	$\alpha_1 = 0$
$p = -$	$p = -$
$\ell = .603$	$\ell = .635$

STA.	F.P & A.P	1	2	3	4	5	6	7	8	9
C_t	0	.04096	-.01728	-.03072	-.00896	0	-.00896	-.03072	-.01728	.04096
C_ℓ	0	-.00768	-.00576	+.00576	+.00768	0	+.00768	+.00576	-.00576	-.00768
C_f	0	1.2288	2.0736	1.3824	0.3072	0	0.3072	1.3824	2.0736	1.2288
C_y	0	-.5565	-.7194	-.0086	+.7885	1.00	+.7885	-.0086	-.7194	-.5565
$t \cdot C_t$	0	.0292	-.0123	-.0219	-.0064	0	-.0107	-.0366	-.0206	+.0488
$\alpha_1 \cdot C_{\ell_1}$										
ℓC_f	0	.7410	1.2500	.8350	.1852	0	.1950	.8780	1.3170	.7800
A	0	.2137	.5183	.8045	.9673	1.000	.9728	.8328	.5770	.2723

EWD.
AUD.
LR

TABLE XIII

HULL SERIES - 40 WATERPLANE

COEFFICIENTS

$b = .576$

$p = .756$

$\ell = .620$

$m = .930$

PARAMETERS

FWD	AFT.
$t = 2.842$	$t = 3.172$
$\alpha_1 =$	$\alpha_1 =$
$p = .745$	$p = .767$
ℓ —	ℓ —

STA	F.P & A.P	1	2	3	4	5	6	7	8	9
C_t	0	.04096	−.01728	−.03072	−.00896	.0	−.00896	−.03072	−.01728	.04096
C_{α_1}	0	−.00768	−.00576	+.00576	+.00768	0	+.00768	+.00576	−.00576	−.00768
C_f	0	1.2288	2.0736	1.3824	0.3072	0	0.3072	1.3824	2.0736	1.2288
C_y	0	−.5565	−.7194	−.0086	+.7885	1.000	.7885	−.0086	−.7194	−.5565
$t\,C_t$	0	.1165	−.0491	−.0874	−.0255	0	−.0284	−.0974	−.0548	.1298
$\alpha_1\,C_{\alpha_1}$										
$p\,C_p$	0	.9150	1.5450	1.0300	.2290	0	.2355	1.0600	1.5888	0.9410
Y_3	0	.4750	.7765	.9340	.9920	1.000	.9956	.9540	.8146	.5143

Ed. J.
R.D.H.
LR

TABLE XIV

CONSTANTS FOR SECTIONS

HULL NO – 40

$b = .576$

$p = .756$

$l = .620$

$m = .930$

STA.	A	A.m	y_b	m_3	f	$f/2$	$m_3 - f/2$	$1-f$	m_0	L	1-L	f(1-L)	1-f(1-L)	R		
1	.2137	.1985	.4730	.4180	1.273	.636	–	–	–	–	–	–	–	0		
2	.6183	.4820	.7765	.6210	.597	.298	.3230	.403	.8000	.182	.818	.489	.511	2.810		
3	.8045	.7480	.9340	.8010	0	0	.8010	1.0	.8010							
4	.9673	.9000	.9920	.9080	0	0	.9080	1.0	.9080							
5	1.000	.9300	1.00	.9300	0	0	.9300	1.0	.9300							
6	.9728	.9040	.9956	.9080	0	0	.9080	1.0	.9080							
7	.8328	.7740	.9540	.8110	0	0	.8110	1.0	.8110							
8	.5770	.5370	.8146	.6600	.466	.233	.4270	.534	.800	.182	.818	.382	.618	3.395		
9	.2723	.2535	.5143	.4930	1.023	.512	–	–	–	–	–	–	–	0		

$$m_3 = \left[\frac{A.m}{y_b}\right] \qquad m_0 = \left[\frac{m_3 - f/2}{1-f}\right] \qquad R = \left[\frac{1 - f(1-L)}{L}\right]$$

Exp. for R

$$f = \left[\frac{8 - 10m_3}{3}\right] \qquad m_3 > 0.80 \quad f = 0$$

TABLE XV

HYPERBOLIC SECTIONS

HULL NO - 40

STATION NO - 4

$f = 0$

$(1-f) = 1$

$m_0 = .9080$

$y_6 = .9920$

W.L X	.05	.10	.20	.30	.40	50	.60	.70	.80	.90	1.0	1.20	1.40	1.60	1.80	2.00
ϕx	.5410	.7240	.8680	.9280	.9580	.9760	.9880	.9940	.9960	.9980	1.000					
$(1-f)\cdot \phi x$																
$f \cdot x$																
y_5																
Y	2.685	3.590	4.310	4.600	4.760	4.850	4.910	4.930	4.940	4.950	4.960	4.960	4.960	4.960	4.960	4.960

Ed J.
K D B.
L.R.

$$Y = \left[5 \times y_6 \times y_5 \right]$$

$$y_5 = f \cdot x + \left[1 - f \right] \left[\phi x \right]$$

TABLE XVI

FOURTH - POWER SECTIONS

HULL No - 40

STATION No - 2

$m_3 = .6210$

$f = .597$

$R = 2.810$

$\frac{y}{b} = .7765$

X	.05	.10	.20	.30	.40	.50	.60	.70	.80	.90	1.00	1.20	1.40	1.60	1.80	2.00
M	.06769	.2430	.7680	1.323	1.728	1.875	1.728	1.323	.7680	.2430	0	1.728				
F	.00327	.01125	.03200	.04725	.04800	.03125	0	-.03675	-.0640	-.06075	0	.4320				
L	.03948	.06075	.06400	.03675	0	-.03125	-.04800	-.04725	-.03200	-.01125	0	-.09600				
Y	-.0266	-.0935	-.2800	-.4455	-.5120	-.4375	-.2160	.1225	.5120	.8505	1.0	0				
$m_3 M$	.0420	.1510	.4770	.8220	1.0730	1.1650	1.0730	.8220	.4770	.1510	.0					
f.F	.0019	.0067	.0191	.0282	.0287	.0187	0	-.0219	-.0382	-.0363	0					
R.L	.1110	.1709	.1800	.1028	0	-.0879	-.1350	-.1328	-.0900	-.0316	0					
y_3	.1283	.2351	.3961	.5075	.5897	.6583	.7220	.7898	.8608	.9336	1.000					
Y	.4980	.913	1.54	1.97	2.29	2.56	2.80	3.06	3.34	3.62	3.88	4.11	4.24	4.33	4.38	4.40

Ed. J. Rod. S.R.

$$Y = \left[5 \times y_b \times y_3 \right]$$

$$y_3 = \left[Y + m_3 M + f F + R L \right]$$

REFERENCES.

1. Taylor, D. W.; "The Speed and Power of Ships", The United States Maritime Commission, 1943.

2. Le Besnerais, M.; "Theorie du Navire", Armand Colin, Paris, 1923.

3. Kelley, A. P.; Jones, S. C.; Crawford, J. W.; and Gooding, R. C.; "A Method of Predicting Statical Stability", Thesis submitted for M.S. Degree, M. I. T., 1946.

4. Randall, J. H.; Stark, R. E.; and Meyer, E. R.; "A Method of Predicting Statical Stability from Hull Coefficients", Thesis submitted for M.S. Degree, M. I. T., 1948.

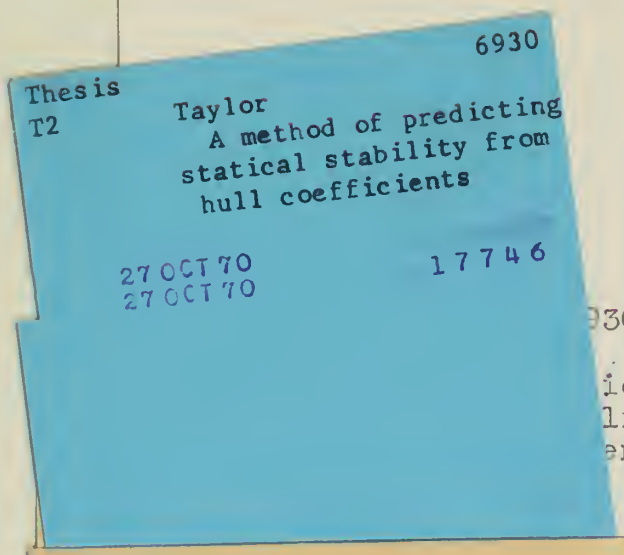
5. Atwood, Edward L.; "Theoretical Naval Architecture", Revised by Pengelly, H. S., Longman's, 1931.

6. Taylor, D. W.; "Calculations for Ship's Forms and the Light Thrown by Model Experiments upon Resistance, Propulsion, and Rolling of Ships", Appendix I, Transactions of the International Engineering Congress, San Francisco, California, 1915.

7. Manning, George C.; "The Basic Design of Ships", D. Van Nostrand Company, Inc., 1945.

8. Rossell, Henry E. and Chapman, Lawrence B.; "Principles of Naval Architecture", Volume I., The Society of Naval Architects and Marine Engineers, 1942.

AUG 31
27 OCT 70
BINDERY
17746



Thesis 6930
T2 Taylor
A method of predicting
statical stability from
hull coefficients.

Library
U. S. Naval Postgraduate School
Monterey, California

ARTISAN
GOLD LETTERING
AND
SMITH BINDERY
OAKLAND, CALIF

thesT2
A method of predicting statical stabilit
3 2768 002 03393 8
DUDLEY KNOX LIBRARY